



Specialist for Pumping Technology

Session 46 – Engineering Analyses for Pumps

Simon Smith January 2026



Presenter Profile – Simon Smith

Simon graduated with an honours degree in Chemical Engineering from the University of Surrey in 1978 and began a long career in the engineered pump industry spanning 45 years (so far!) with Peerless Pump, BW/IP International / Flowserve, SPP Pumps, Ruhrpumpen and Ebara Cryodynamics.

Over his long career he has filled various roles as Applications Engineer / Manager, Project Manager, Key Account Specialist, Vertical Pump Product Specialist, International Sales Engineer / Manager / Director and he has considerable experience in Training & Mentoring young engineers.





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Here is a listing of all the previous courses in the last two years.

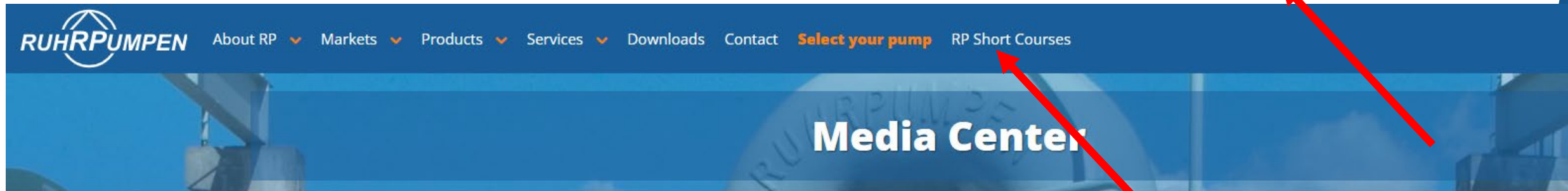
- No 25 – Magnetic Drive Pumps
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- No 27 – The Importance of System Curves
- No 28 – NPSH & Nss Made Simple
- No 29 – Curve Shape, Head Rise & Allowable Tolerances
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- No 31 - Comparison of API610 12th & 11th Editions
- No 32 - Pump Instrumentation
- No 33 - Handling Viscous Fluids with Centrifugal Pumps
- No 34 - Fire Pumps for the Oil & Gas Industries
- No 35 - Vertical Sump Pumps (Type VS4)
- No 36 - Engineered Systems
- No 37 - BB5 Double Case Barrel Pumps
- No 38 - Start-Up, Commissioning & Trouble Shooting
- No 39 – Positive Displacement Pumps
- No 40 – Vertical Pumps Part 1 VS1,2,3
- No 41 – Vertical Pumps Part 2 VS4,5,6,7
- No 42 & 43 – Performance Testing & Inspection of API610 Pumps
- No 44 – Non-Destructive Examination
- No 45 – Customer Specification Requirements

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Simon Smith
Solutions Expert

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SHORT COURSE 45

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- Q&A Report



RuhRPumpen Short Courses

Session 46 – “Engineering Analyses for Pumps”

Aimed at Process and Mechanical Engineers, and Consultant Engineers who specify pumping equipment as well as Applications & Sales Engineers selecting and quoting them.

This course will give an overview of the various Engineering Analyses that are available – Structural Analysis, Seismic Analysis, Finite Element Analysis, Modal Analysis, Lateral Analysis, & Torsional Analysis.

It will explain the what, the why and the how as well as the customer benefits of these analyses and will show some sample reports.

Course Material by : Maulik Shah, Senior Inside Sales Engineer, Houston, TX

Contents

1. Stress and Displacements Analysis
2. Seismic Analysis
 - A. Anchor bolt reactions with calculator
 - B. Anchor bolt reactions with FEA
 - C. Anchor bolt reactions and structure analysis with FEA
3. Modal Analysis
4. Rotodynamic Analyses
 - A. Lateral Analysis
 - B. Torsional Analysis
 - C. Transient torsional analysis

1- Structural (Stress and Displacements) Analysis

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1- Structural (Stress and Displacements) Analysis

What is it and why it is needed ?

- This analysis evaluates the shaft deflection at the pump shaft end resulting from the application of suction and discharge nozzle loads, as specified in the API allowable load tables.
- The calculated deflections are then compared against the API criteria to confirm compliance.
- It answers two key questions:
 - Stress Analysis – “Will it be strong enough?”
 - Displacement Analysis – “Will it deform too much?”

What is customer's benefit ?

Structural (stress & displacement) engineering analysis ensures that a component or structure:

- Is strong enough
- Does not deform excessively
- Meets required standards (e.g., API 610)
- Will operate safely and reliably throughout its life
- maintains alignment integrity under external piping loads, preventing operational issues and premature wear

1- Structural (Stress and Displacements) Analysis

What the potential danger is if not done:

If structural stress and displacement analysis is not performed, you risk:

- Equipment failure
- Fluid leaks and safety hazards
- Pump/motor misalignment and vibration
- Fatigue damage and short equipment life
- Non-compliance with API 610
- Higher operating and maintenance costs

What does it cost?

Indicative pricing - \$6,000 - \$7,000

1- Structural (Stress and Displacements) Analysis

RP format analysis simple (as provided to customer) :

	SCE-L 2x1x10 – Structural Analysis (Baseplate Nozzle Load Test)	EHP-RP0029 04-09-2025
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6. Results

6.1. Displacement in Z due to M_{yc}

The maximum displacement at the shaft end is obtained in Case 2, with a value of 214 μm . Figure 5 shows the results and the deformed view.

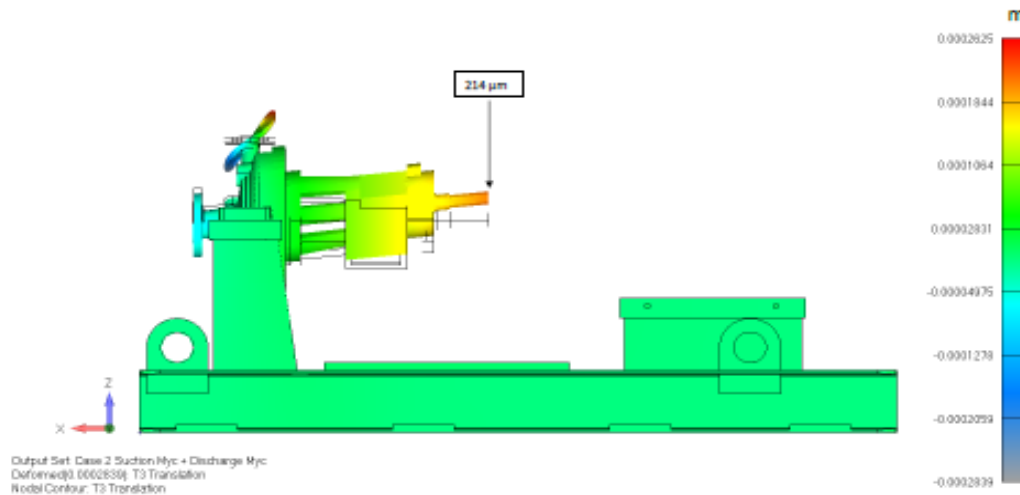


Figure 5. Displacement Results.

	SCE-L 2x1x10 – Structural Analysis (Baseplate Nozzle Load Test)	EHP-RP0029 04-09-2025
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6.2. Displacement in Y due to M_{zc}

The maximum displacement at the shaft end is obtained in Case 3, with a value of 125 μm . Figure 6 shows the results and the deformed view.

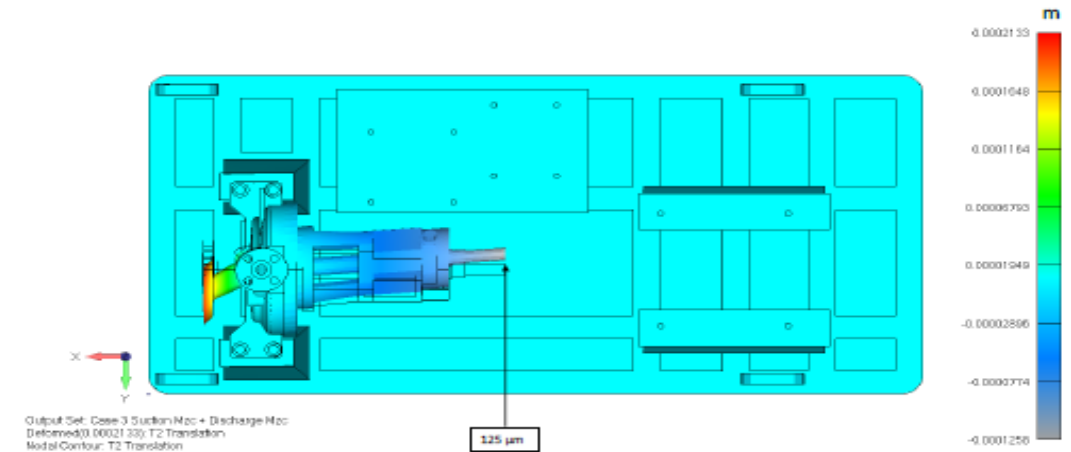


Figure 6. Displacement Results.

1- Structural (Stress and Displacements) Analysis

	SCE-L 2x1x10 – Structural Analysis (Baseplate Nozzle Load Test)	EHP-RP0029 04-09-2025
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7. Conclusions

As can be seen in Figure 5 and Figure 6, the maximum displacements at the pump shaft end for M_{Yc} and M_{Zc} cases are 214 μm and 125 μm , respectively. Since the values of the flange moments according to Table 5 of API 610 12th Edition are being considered three times, the acceptable displacement must be less than 0.015 in. (380 μm), as stated in Annex F of the same standard. This way the maximum displacements obtained in the analysis can be regarded as acceptable. Table 4 shows the permissible pump shaft displacement according to API and the maximum shaft displacement obtained from the analysis.

Table 4. Stiffness Test Acceptance Criteria.

	Permissible Pump Shaft Displacement (μm)		Maximum Shaft Displacement (μm)	Direction
	Baseplate not Intended for Grouting	Baseplate not Intended for Grouting (3x)		
M_{Yc}	125	380	214	+Z
M_{Zc}	50	380	125	-Y

The results presented herein are only valid under the criteria and considerations previously described.

2A- Seismic Analysis – Anchor Bolt Reactions with Calculator

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2A- Seismic Analysis – Anchor Bolt Reactions with Calculator

What is Seismic Analysis?

Seismic analysis evaluates how equipment responds to earthquake ground motion. For industrial equipment (including pumps, tanks, skids), it is used to determine:

- Base shear (horizontal seismic force)
- Overturning moment
- Anchor bolt tension & shear loads
- Whether the foundation and bolts are strong enough

It ensures that during an earthquake the equipment does not slide, tip, or pull bolts out of the foundation.

2A- Seismic Analysis – Anchor Bolt Reactions with Calculator

Anchor Bolt Reactions – What You Calculate

To check the anchorage, you must calculate:

- Horizontal shear load (V) on bolts & grout
- Overturning moment (M) caused by seismic forces
- Bolt tension (T) from the overturning
- Bolt shear (V_b) from horizontal forces
- Bolt utilization (compared to allowable capacity)

2A- Seismic Analysis – Anchor Bolt Reactions with Calculator

What is it and why it is needed ?

- A simplified method to estimate anchor bolt forces due to seismic loads, based on static calculations or code formulas.
- Why seismic and anchor bolt analysis is needed:
 - To keep equipment stable
 - To prevent leaks and failures To protect people
 - To meet code and project requirements
 - To avoid costly downtime and damage

2A- Seismic Analysis – Anchor Bolt Reactions with Calculator

What is customer's benefit ?

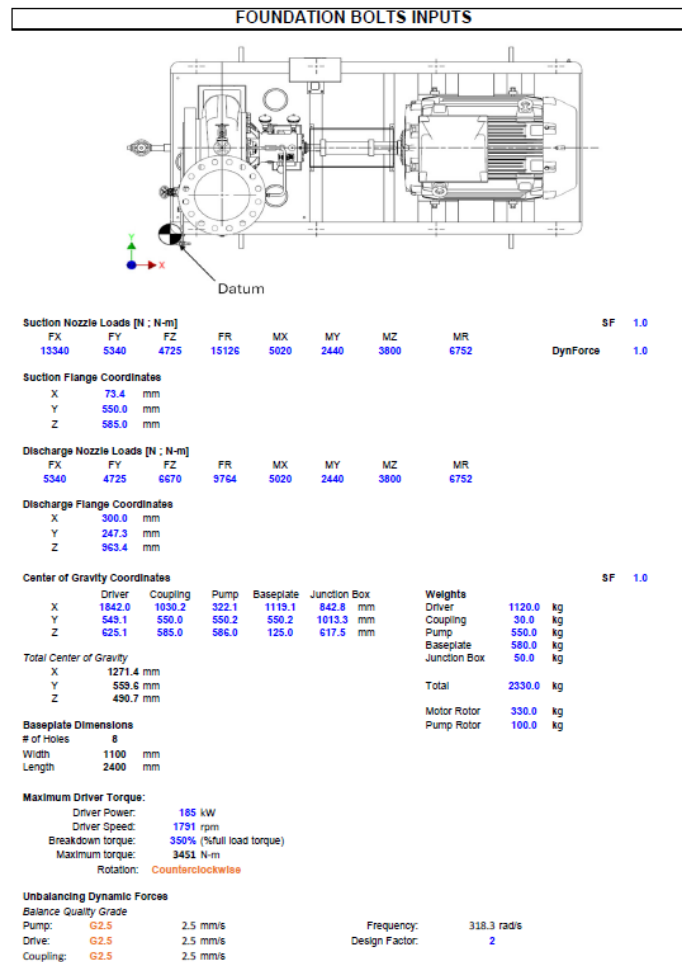
- Quick verification of anchor bolt diameter and layout adequacy for basic seismic requirements, without detailed structural modeling.
- Anchor bolt reactions are essential for the civil engineering team since they provide the necessary input to design the concrete foundation or slab supporting the pump
- Protection of Piping and Connected Systems
- Compliance With Codes and Plant Specifications
- Reduced Installation Risk
- Assurance That the Equipment Will Survive Earthquake Events
- Increased Equipment Life

What does it cost?

Indicative pricing - \$500 -\$600

2A- Seismic Analysis – Anchor Bolt Reactions with Calculator

RP format analysis simple (as provided to customer) :

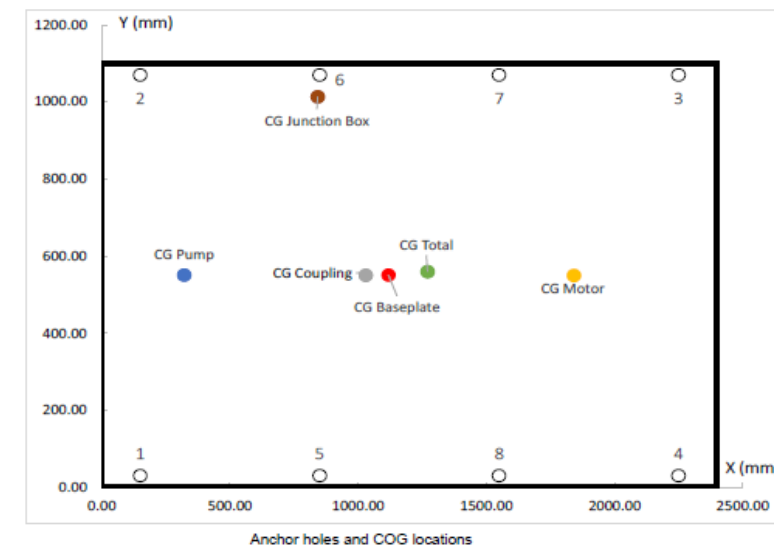


BOLT LOCATION

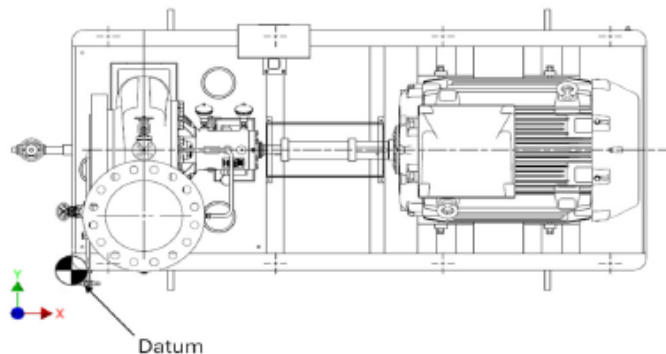
Anchor #	Position [mm]	
	X	Y
1	150.1	30.0
2	150.1	1069.8
3	2249.9	1069.8
4	2249.9	30.0
5	850.1	30.0
6	850.1	1069.8
7	1549.9	1069.8
8	1549.9	30.0

Bolt's Properties

Number of Bolts	8
Bolt's Diameter	3/4 in
Tensile Stress Area	215 mm ² = 0.334 in ²
Bolt's Yield Strength	205 MPa
Bolt's Material	Duplex anchor bolts, with a minimum of 205 MPa yield strength



FOUNDATION BOLTS INPUTS



Suction Nozzle Loads [N ; N-m]								SF	1.0
FX	FY	FZ	FR	MX	MY	MZ	MR		
13340	5340	4725	15126	5020	2440	3800	6752	DynForce	1.0

Suction Flange Coordinates		
X	Y	Z
73.4 mm	550.0 mm	585.0 mm

Discharge Nozzle Loads [N ; N-m]						
FX	FY	FZ	FR	MX	MY	MZ
5340	4725	6670	9764	5020	2440	3800

Discharge Flange Coordinates		
X	Y	Z
300.0 mm	247.3 mm	963.4 mm

Center of Gravity Coordinates								SF	1.0
	Driver	Coupling	Pump	Baseplate	Junction Box	Weights			
X	1842.0	1030.2	322.1	1119.1	842.8 mm	Driver	1120.0 kg		
Y	549.1	550.0	550.2	550.2	1013.3 mm	Coupling	30.0 kg		
Z	625.1	585.0	586.0	125.0	617.5 mm	Pump	550.0 kg		

Total Center of Gravity		
X	Y	Z
1271.4 mm	559.6 mm	490.7 mm

Baseplate Dimensions		
# of Holes	Width	Length
8	1100 mm	2400 mm

Maximum Driver Torque:		
Driver Power:	185 kW	
Driver Speed:	1791 rpm	
Breakdown torque:	350% (%full load torque)	
Maximum torque:	3451 N-m	
Rotation:	Counterclockwise	

Unbalancing Dynamic Forces		
Balance Quality Grade		
Pump:	G2.5	2.5 mm/s
Drive:	G2.5	2.5 mm/s
Coupling:	G2.5	2.5 mm/s

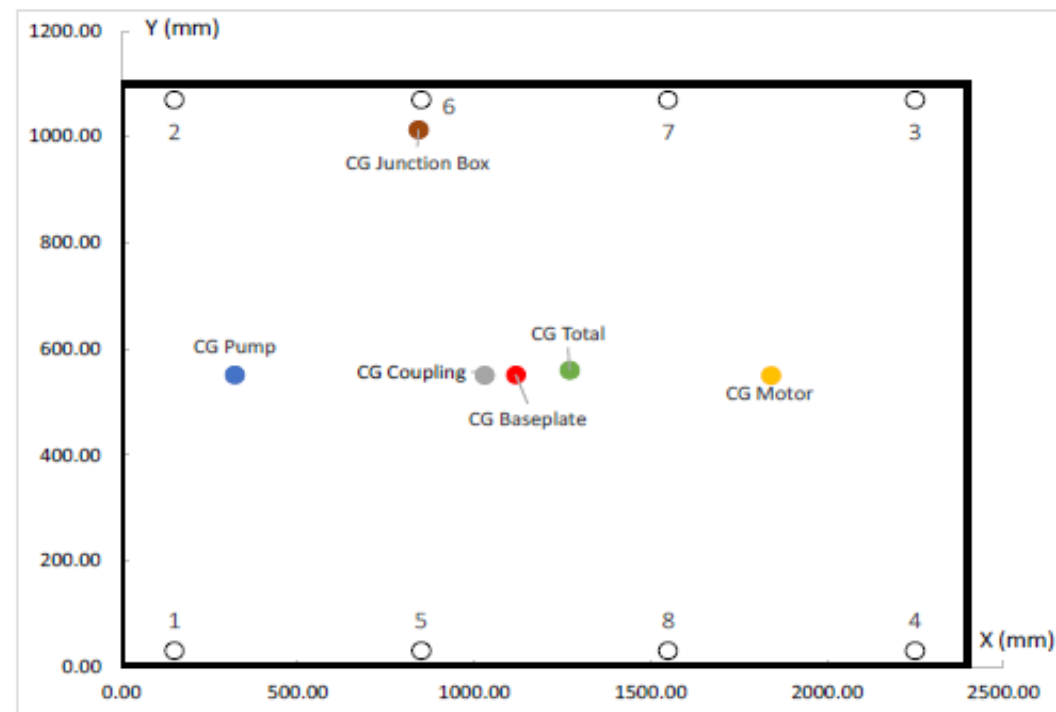
Frequency:	318.3 rad/s
Design Factor:	2

BOLT LOCATION

Anchor #	Position [mm]	
	X	Y
1	150.1	30.0
2	150.1	1069.8
3	2249.9	1069.8
4	2249.9	30.0
5	850.1	30.0
6	850.1	1069.8
7	1549.9	1069.8
8	1549.9	30.0

Bolt's Properties

Number of Bolts	8
Bolt's Diameter	3/4 in
Tensile Stress Area	215 mm ² = 0.334 in ²
Bolt's Yield Strength	205 MPa
Bolt's Material	Duplex anchor bolts, with a minimum of 205 MPa yield strength



Anchor holes and COG locations



2B- Seismic Analysis – Anchor Bolt Reactions with FEA (Anchor Bolt Sizing Only)

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with FEA (Anchor Bolt Sizing Only)

2B- Seismic Analysis – Anchor Bolt Reactions with FEA (Anchor Bolt Sizing Only)

What is it and why it is needed ?

Seismic analysis with Finite Element Analysis (FEA) evaluates how a pump, skid, or any mechanical equipment responds to earthquake forces by modeling the structural stiffness, mass distribution, and load paths in detail.

Unlike simple hand calculations, FEA captures:

- Real geometry
- Welds, ribs, stiffeners
- Baseplate flexibility
- Actual bolt locations
- Accurate stress distribution
- 3D load paths

This produces highly accurate reactions at the anchor bolts and realistic deformation predictions.

2B- Seismic Analysis – Anchor Bolt Reactions with FEA (Anchor Bolt Sizing Only)

Why FEA Is Used

Seismic loads are dynamic and involve complex structural behavior.

FEA provides:

- Much more accurate anchor bolt forces

 - Because it considers flexibility of the baseplate, pump casing, grout, and skid.

- Accurate stress and displacement results

 - Ensuring the equipment does not exceed material limits during an earthquake.

- Realistic nozzle and piping interface reactions

 - Critical for API 610 compliance.

- Visualization of weak areas

 - Allowing optimized design (thicker baseplate, additional ribs, larger bolts).

- Confidence in safety and code compliance

 - Often required by EPCs and plant owners.

2B- Seismic Analysis – Anchor Bolt Reactions with FEA (Anchor Bolt Sizing Only)

What is customer's benefit ?

- Higher accuracy than hand calculations
Provides confidence that anchors and foundations will perform in real earthquake conditions.
- Prevents failures
Avoids sliding, overturning, bolt breakage, and piping damage.
- Optimizes design
Ensures the baseplate, grout, and bolts are neither under-nor over-designed.
- Increases reliability & uptime
Less vibration, better alignment retention, fewer failures.
- Ensures standards compliance
Many EPCs, refineries, and chemical plants require FEA for seismic zones.

What does it cost?

Indicative pricing - \$4,500 - \$5,000



2C- Seismic Analysis – Anchor Bolt Reactions and Structural Analysis with FEA

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2C- Seismic Analysis – Anchor Bolt Reactions and Structural Analysis with FEA

What is it and why it is needed ?

- This combined analysis evaluates how the equipment (pump, baseplate, skid, or structural frame) performs under **seismic loading**, and how those loads transfer through the baseplate into the **anchor bolts**, concrete foundation, and connected piping.
- Using **Finite Element Analysis (FEA)** provides a realistic, high-fidelity assessment of stresses, deflections, and anchorage forces to ensure reliability and safety during earthquake conditions

What does it cost?

Indicative pricing - \$6,000 - \$7,000

2C- Seismic Analysis – Anchor Bolt Reactions and Structural Analysis with FEA

What is customer's benefit ?

- **Safety & Structural Integrity**
Ensures the equipment remains stable during earthquakes—preventing tipping, sliding, or bolt failure.
- **Protection of Piping & Connected Systems**
Reduces the risk of nozzle damage, flange leaks, or pipe rupture during seismic events.
- **Longer Equipment Life**
Lower deflection and stress improve alignment, reduce vibration, and extend seal/bearing life.
- **Code & Project Compliance**
Meets various code and industrial requirements for seismic anchorage.
- **Reduced Installation & O&M Costs**
Accurate bolt reactions prevent overdesign or under design of foundations and avoid costly field modifications.
- **Higher Reliability**
Equipment remains operational after seismic events with minimized downtime.

2C- Seismic Analysis – Anchor Bolt Reactions and Structural Analysis with FEA

RP format analysis simple (as provided to customer) :

	VMF 30VMM 1 Stage – Seismic Analysis	BLB-RP0118 24-09-2025
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5. Constraints

The pump was modeled on a representative foundation model that simulates the on-site installation conditions. The bottom surface of this foundation model was constrained as fixed. The connection between the pump soleplate and the representative foundation model was considered as a linear contact. Additionally, four beam elements (representing the anchor bolts) were used to connect the pump to the representative foundation model. Figure 5 shows the model constraints.

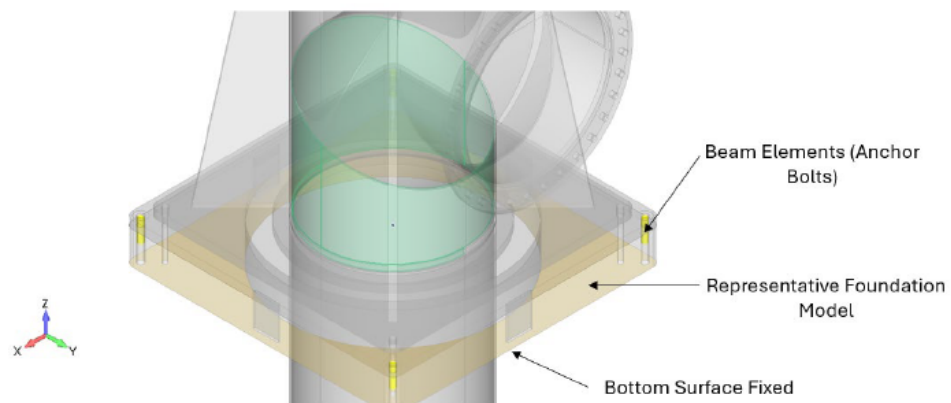


Figure 5. Constrained Model.

	VMF 30VMM 1 Stage – Seismic Analysis	BLB-RP0118 24-09-2025
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6. Results

6.1. Von Mises Stress – Load Combination #1

The maximum Von Mises stress obtained is **43.25 MPa** and it is located at the nozzle head discharge pipe. The maximum stress obtained is shown in Figure 6.

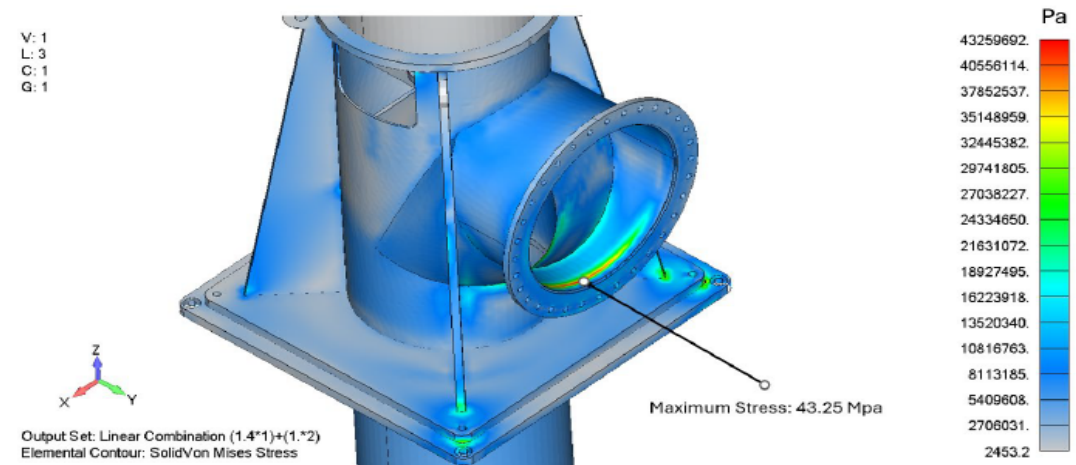


Figure 6. Von Mises Stress – Load Combination #1.

2C- Seismic Analysis – Anchor Bolt Reactions and Structural Analysis with FEA

	VMF 30VMM 1 Stage – Seismic Analysis	BLB-RP0118 24-09-2025
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6.2. Von Mises Stress – Load Combination #2

The maximum Von Mises stress obtained is **97.31 MPa** and it is located at one of the windows of the nozzle head. The maximum stress obtained is shown in Figure 7.

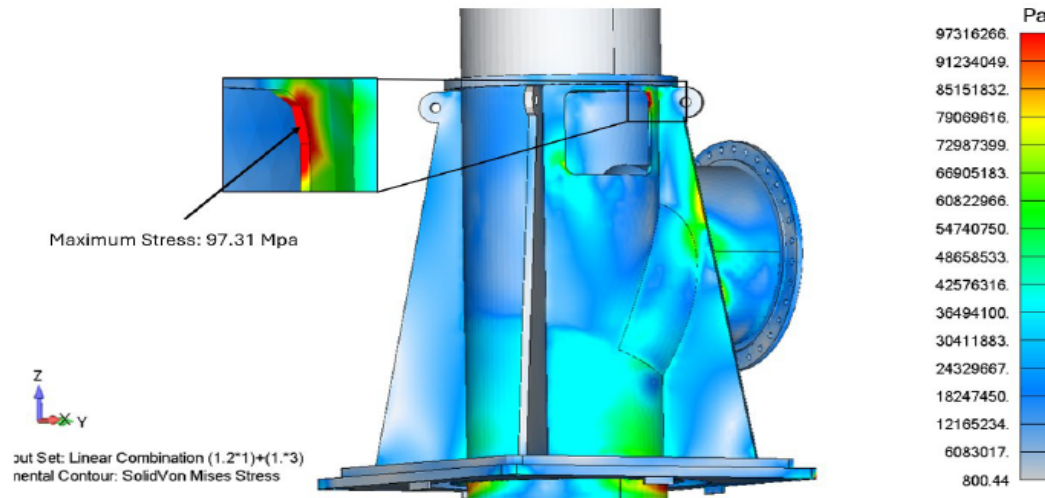


Figure 7. Von Mises Stress – Load Combination #2.

	VMF 30VMM 1 Stage – Seismic Analysis	BLB-RP0118 24-09-2025
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7. Anchor Bolt Reactions Forces and Validation

The pump is anchored in place with four 1.375-inch anchor bolts. Figure 8 shows their location. The reactions forces were calculated for each of them for each load combination cases mentioned in Section 4 of this report. Table 3 shows the anchor bolt reactions while Table 4 shows the bolts validation and the safety factor respects the allowable stress obtained for each bolt for each combination case.

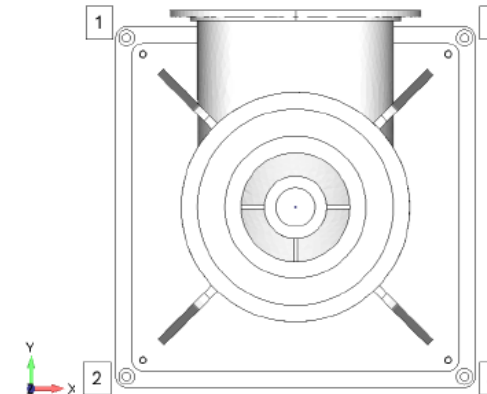


Figure 8. Anchor Bolt Locations (Top View).

Table 3. Anchor Bolt Reactions.

Combination Load	Anchor	Bolt Reactions Forces (N)		
		F _x	F _y	F _z ⁽¹⁾
1	1	-3392.133	-9440.244	40938.52
	2	-2263.934	-7473.88	1992.904
	3	1931.726	-6850.655	33110.38
	4	-2606.385	-5513.056	21.92758
2	1	-38814.98	37035.61	10692.07
	2	-37566.6	38237.52	32972.64
	3	-34787.03	35205.88	41765.88
	4	-36088.7	36641.18	13738.64

5. Constraints

The pump was modeled on a representative foundation model that simulates the on-site installation conditions. The bottom surface of this foundation model was constrained as fixed. The connection between the pump soleplate and the representative foundation model was considered as a linear contact. Additionally, four beam elements (representing the anchor bolts) were used to connect the pump to the representative foundation model. Figure 5 shows the model constraints.

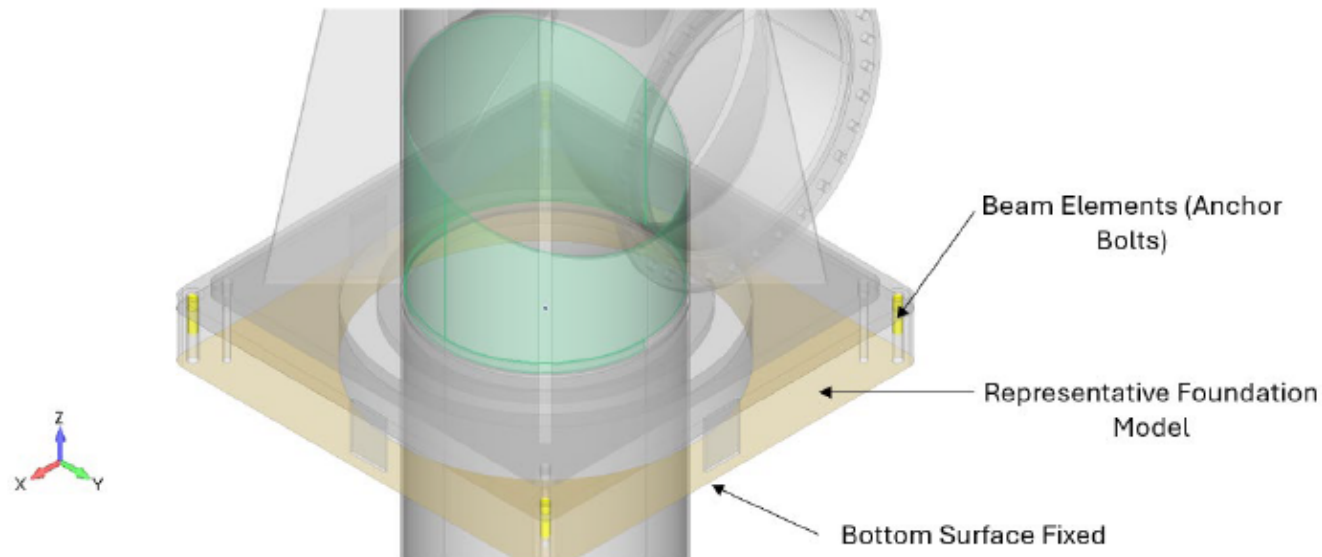


Figure 5. Constrained Model.

6. Results

6.1. Von Mises Stress – Load Combination #1

The maximum Von Mises stress obtained is **43.25 MPa** and it is located at the nozzle head discharge pipe. The maximum stress obtained is shown in Figure 6.

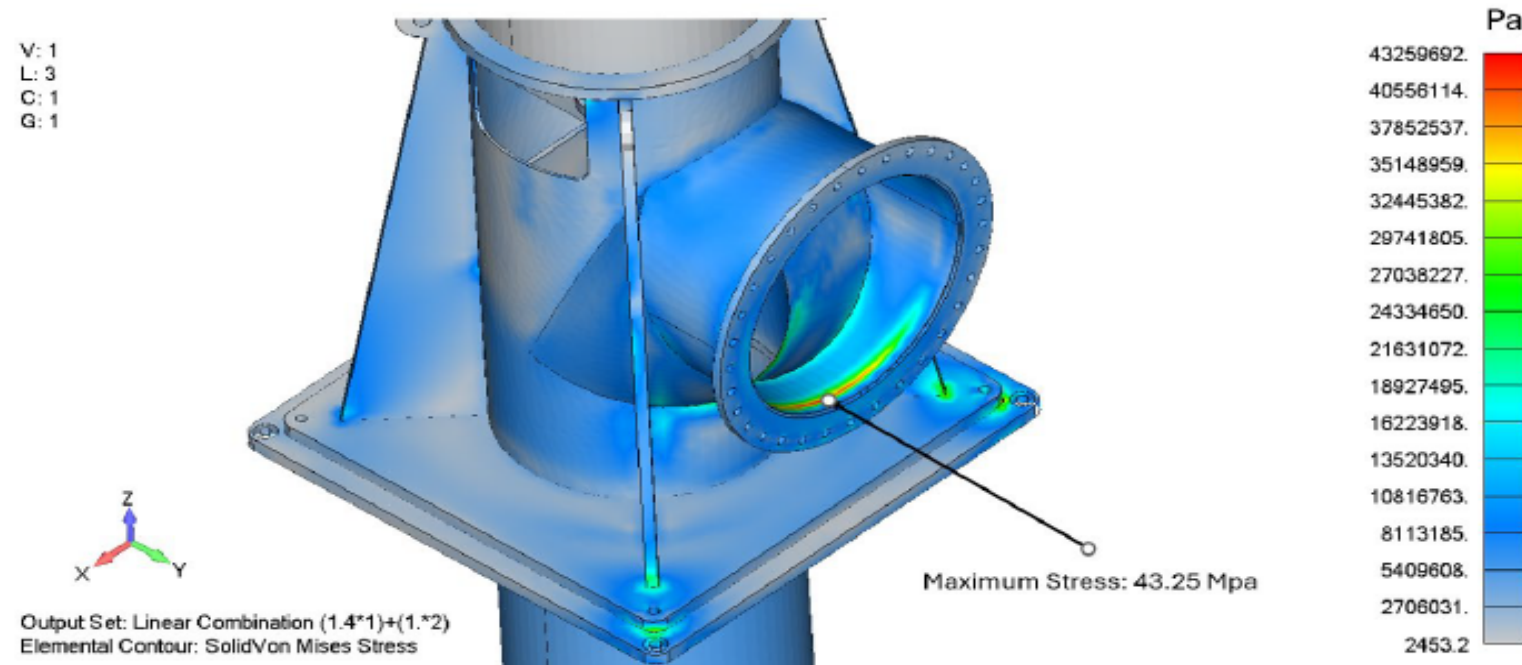


Figure 6. Von Mises Stress – Load Combination #1.

6.2. Von Mises Stress – Load Combination #2

The maximum Von Mises stress obtained is **97.31 MPa** and it is located at one of the windows of the nozzle head. The maximum stress obtained is shown in Figure 7.

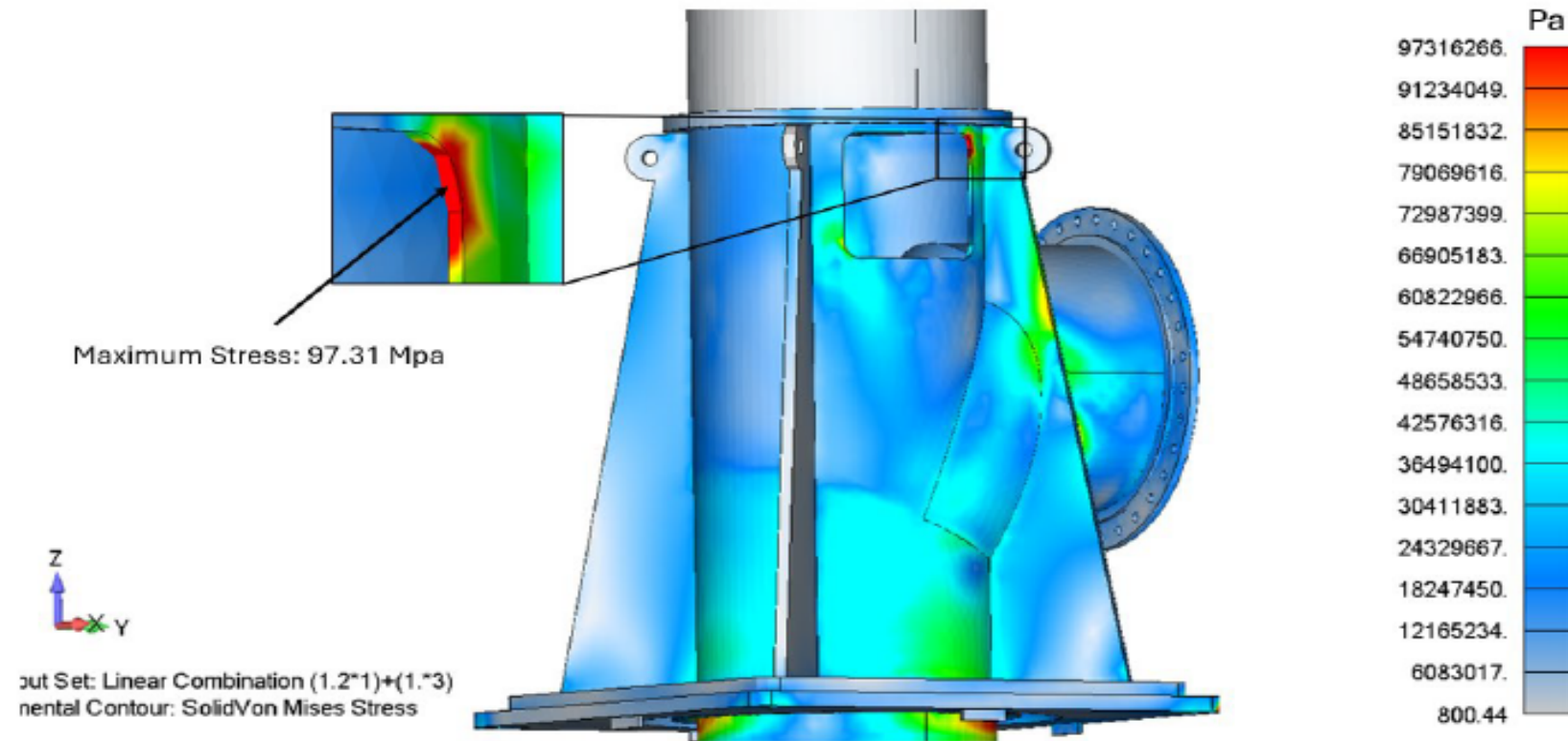


Figure 7. Von Mises Stress – Load Combination #2.

7. Anchor Bolt Reactions Forces and Validation

The pump is anchored in place with four 1.375-inch anchor bolts. Figure 8 shows their location. The reactions forces were calculated for each of them for each load combination cases mentioned in Section 4 of this report. Table 3 shows the anchor bolt reactions while Table 4 shows the bolts validation and the safety factor respects the allowable stress obtained for each bolt for each combination case.

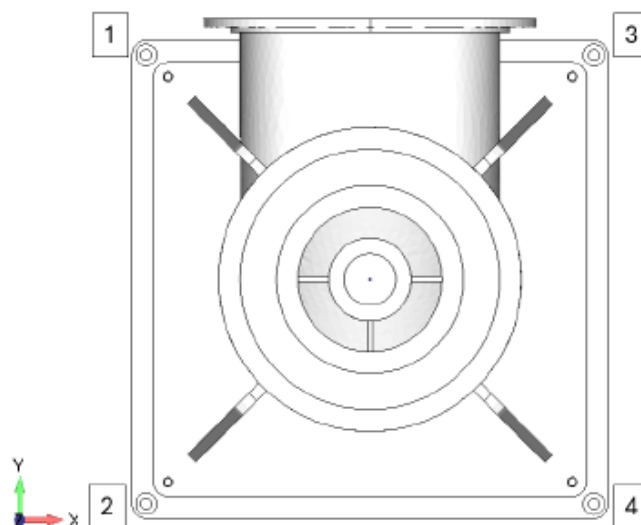


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2	1	-38814.98	37035.61	10892.07
	2	-37586.6	38237.52	32972.64
	3	-34787.03	35205.88	41765.88
	4	-36088.7	36641.18	13738.64

2C- Seismic Analysis – Anchor Bolt Reactions and Structural Analysis with FEA

	VMF 30VMM 1 Stage – Seismic Analysis	BLB-RP0118 24-09-2025
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9. Conclusions

As can be seen in the obtained results, the maximum stress obtained in the model is 97.31 MPa for the load combination #2 and it is located at one of the windows of the nozzle head discharge pipe.

The maximum allowable stress is defined as $\frac{2}{3}$ of the material yield strength. In this case, the nozzle head material is A105 with a yield strength of 250 MPa. Thus, the maximum allowable stress is 166.66 Mpa. A safety factor of 1.71 was calculated.

Since the safety factor obtained is higher than 1.0, it is concluded that the VMF 30VMM 1 Stage pump is able to withstand the combination load cases.

2C- Seismic Analysis – Anchor Bolt Reactions and Structural Analysis with FEA

On the other hand, the reaction forces and stresses in the anchor bolts were calculated to validate them. The anchor bolts have a diameter of 1.375 inches and are made of ASTM F1554 material, (as recommended from API 686). The criteria used to validate the bolts is that all bolts need a safety factor higher than 1.50 in order to be suitable to withstand the loads combination, thus ensuring that the stresses on the bolts will not exceed the allowable stress defined in section 7. As can be seen in Table 4, the safety factors of all the combination sets are higher than 1.50, therefore, the anchor bolts are suitable for the load's combinations considering the size and the materials previously described. A different material for the anchor bolts can be used as long as the yield material is equal to or greater than 248 MPa.

The results presented herein are only valid under the considerations and criteria previously described.

3- Modal Analysis

3- Modal Analysis

3- Modal Analysis

What is it and why it is needed ?

Pump modal analysis evaluates the **dynamic behavior** of a complete pump assembly by calculating its **natural frequencies** (resonance frequencies) and associated **mode shapes**.

The analysis is performed on a 3D FEA model that includes:

- Pump casing
- Motor or driver
- Shaft and rotor if required
- Baseplate or skid
- Stiffeners, grout, support beams
- Anchor-bolt boundary conditions

The result is a detailed understanding of how the structure responds to vibration.

3- Modal Analysis

Why Natural Frequencies Matter

Every mechanical structure has certain frequencies at which it vibrates with large amplitude—its **natural frequencies**.

If any natural frequency is too close to:

- Pump running speed ($1\times$ rpm)
- Blade passing frequency
- Motor electrical frequency
- Piping-induced vibration

...then **resonance** can occur, leading to:

- High vibration
- Seal and bearing failures
- Fatigue cracking
- Nozzle overstress
- Reduced equipment life
- NPSH or hydraulic instability issues (in severe cases)

Modal analysis prevents this.....

3- Modal Analysis

What is customer's benefit ?

- Avoids Resonance
Ensures no natural frequency is within $\pm 20\%$ (or the project requirement) of running speed.
- Reduces Vibration and Noise
Improves pump reliability and hydraulic performance.
- Extends Seal and Bearing Life
Significantly lowers maintenance costs and unplanned downtime.
- Verifies Baseplate and Foundation Stiffness
Ensures the installation supports long-term reliable operation.
- Ensures Piping Does Not Induce Harmful Vibrations
Helps prevent nozzle overload, flange leaks, or pipe fatigue.
- Required by Many EPCs and Refineries
Used for critical services, high-energy pumps, or installations in high-vibration environments.

What does it cost?

Indicative pricing - \$6,000 - \$7,000

3- Modal Analysis

RP format analysis simple (as provided to customer)

	VMT 20KXH 1 Stage – Modal Analysis	BLB-RP0058 23-01-2024
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3.2 Finite Element Model

This analysis was done with Siemens's software FEMAP 2306 with Normal Modes/Eigenvalue analysis option. The geometry was meshed with solid TET 10-noded elements with no gaps between components, simulating with this correct bolting connections. The meshed model is illustrated in Figure 3.

Mesh

- ✓ Nodes: 373,953
- ✓ Elements: 209,331

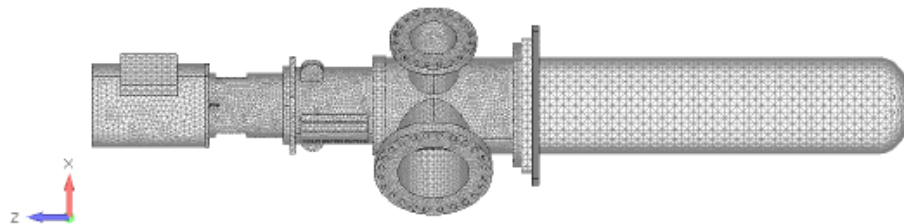


Figure 3. Meshed Model.

3.3 Boundary Conditions

The boundary conditions used for this analysis are shown in Figure 4. Foundation stiffness coefficients provided by the customer for the installation site (Table 4) were incorporated to the analysis using spring elements (CBUSH), rigid elements (RBE2) and gap elements (CGAP) located at the anchor bolt holes and the bottom surface of the soleplate.

	VMT 20KXH 1 Stage – Modal Analysis	BLB-RP0058 23-01-2024
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3.4 Results

Below table shows the first eight natural frequencies for both cases. Figure 5 shows the mode shapes that are within the separation margins, according to data and conditions described in the report. Figure 6 show each natural frequency and the separation margins of +20% and -15% (API 610, 12th Edition) from the operating speed.

Table 5. Natural Frequencies Module

Mode	Frequency [Hz]	Frequency [CPM]	Separation Margin
1st	8.88	532.80	-69.55%
2nd	9.00	540.00	-69.14%
3rd	17.97	1078.20	-38.39%
4th	18.64	1118.40	-36.09%
5th	28.90	1734.00	-0.91%
6th	30.53	1831.80	4.67%
7th	31.12	1867.20	6.70%
8th	40.89	2453.40	40.19%

3- Modal Analysis

RP format analysis simple (as provided to customer)

	VMT 20KXH 1 Stage – Modal Analysis	BLB-RP0058 23-01-2024
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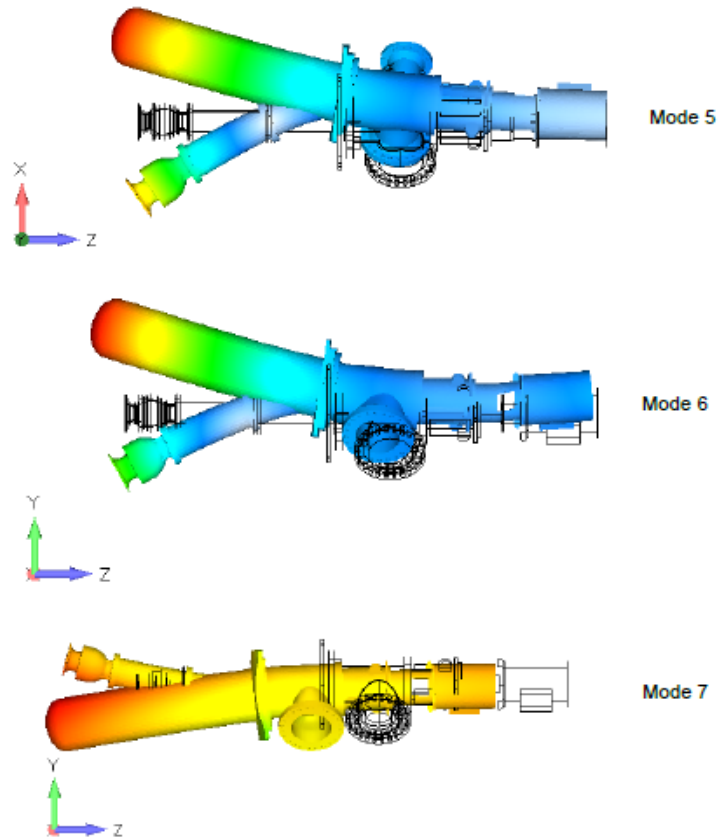


Figure 5. Mode Shapes.

	VMT 20KXH 1 Stage – Modal Analysis	BLB-RP0058 23-01-2024
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5. Conclusions

As can be seen in the obtained results, three natural frequencies were found in the analysis.

A dynamic response analysis was performed to validate those natural frequencies resulting in a maximum vibration velocity of 1.805 mm/s RMS.

According to API 610, 12th Edition, the maximum vibration velocity allowed in the driver mounting surface is 5.0 mm/s RMS. Therefore, the vibration levels of the pumping system are acceptable under this criterion.

The VMT 20KXH 1 Stage pump is suitable to operate at the operating speed range of 1750 rpm.

The results presented herein are only valid under the criteria and considerations previously described.

4A- Rotodynamic Lateral Analysis

4A- Rotodynamic Lateral Analysis

4A- Rotodynamic Lateral Analysis

What is it and why it is needed ?

What It Is

Rotodynamic lateral analysis is a specialized engineering assessment used to evaluate the **dynamic behavior of a rotating shaft system**—including the pump shaft, impellers, bearings, coupling, and motor rotor—when subjected to lateral (radial) vibration forces.

This analysis determines:

- **Critical speeds** (natural frequencies of the rotating system)
- **Mode shapes** (how the shaft bends at each frequency)
- **Bearing stiffness and damping effects**
- **Unbalance response**
- **Amplification factors**
- **Separation margins from running speed**

It ensures the rotating assembly operates safely, smoothly, and without harmful vibration across the entire speed range.

4A- Rotodynamic Lateral Analysis

Why It Is Needed

API 610, API 617, and API 684 require rotodynamic lateral analysis for many pump types, especially high-energy, multistage, or high-speed units.

Without this analysis, the pump could experience:

- Excessive vibration
- Seal failures
- Bearing overheating or premature wear
- Rotor instability
- Shaft fatigue or cracking
- Coupling issues
- Resonance near operating speed

What does it cost?

Indicative pricing - \$7,000 - \$11,000

Lateral analysis report prevents these problems

4A- Rotodynamic Lateral Analysis – API 610 Requirements

9.2.4 Dynamics

9.2.4.1 Lateral Analysis

9.2.4.1.1 Unless otherwise specified, the need for a lateral analysis of a pump's rotor shall be determined using the decision logic set out in Table 18.

Table 18—Decision Logic for Rotor Lateral Analysis

Step	Action
1	Design pump
2	Does a similar pump (3.1.54) or an identical pump (3.1.18) exist? If "yes," go to step 5. If "no," go to step 3.
3	Is rotor classically stiff (3.1.8)? If "yes," go to step 5. If "no," go to step 4.
4	Analysis required
5	Analysis not recommended

- **9.2.4.1.2** If a lateral analysis is required by the process in 9.2.4.1.1, or if specified by the purchaser, it shall be performed in accordance with Annex I and its results assessed in accordance with I.1.2 through I.1.5.

4A- Rotodynamic Lateral Analysis

What is customer's benefit ?

- Lower Vibration Levels
Ensures smooth and quiet operation.
- Longer Bearing & Seal Life
Reduces wear and maintenance downtime.
- Prevention of Resonance Problems
Critical speeds are kept clear of operating speeds.
- Higher Reliability
Especially important for high-speed and high-energy pumps.
- Compliance With API 610/API 684
Often mandatory for refinery, petrochemical, and LNG projects.
- Safe Startup and Shutdown
Verifies rotor stability across the entire speed ramp.

4A- Rotodynamic Lateral Analysis

RP format analysis simple (as provided to customer) :

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The structure model was added to the rotor model once it was tuned to its structural natural frequencies found in a modal analysis. The structure model consists of the thrust pot, nozzle head, discharge, intermediate and suction bowls, barrel, and soleplate, connected to the rotor through the bearings. Since this pump is equipped with a barrel, damping coefficients were assigned to the stations considering that all columns and bowls were submerged in liquid. Referenced to Kovats [4], the modes of the submerged portion have a damping ratio between 0.2 and 0.4 so that vibration is not observable even when running at a critical speed.

Bearing parameters and locations were also provided by Ruhrpumpen. Stiffness and damping values were calculated using XLRotor™ code and are included in the present report.

The detail of the pump model used for the analysis are shown in Figure 1.

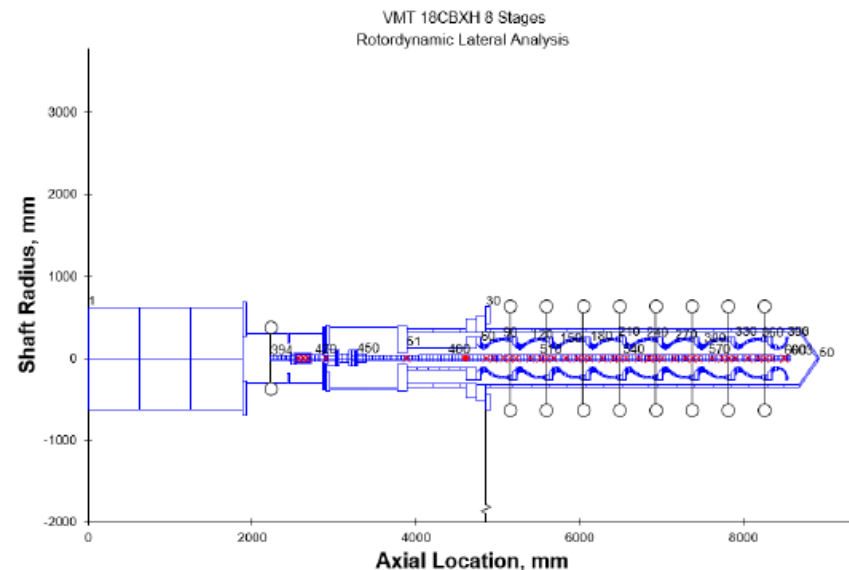


Figure 1: Model for Rotodynamic Lateral Analysis.

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3.3.2.1 As-New Clearances, with Water

Figure 2 shows the damped natural frequency map or lateral Campbell diagram with the operating speed of 1786 rpm marked on it. It also shows the synchronous line. When a natural frequency intersects the synchronous line, the rotor speed of the intersection would be a critical speed. This map covers all the rotor's damped natural frequencies within the frequency range zero to 2.2 times maximum continuous speed, for the speed range 25% to 125% of rated, as specified in API 610, 12th Edition.

Table 4 describes all the natural frequencies displayed in the lateral Campbell diagram for the rated operating speed of 1786 rpm. It includes the separation margin between the damped natural frequencies and the rated speed with the corresponding damping ratio.

The damping factor versus separation margin between natural frequencies and the synchronous run line is shown in Figure 3. According to API 610, 12th Edition, all natural frequencies should be in the "acceptable" region in order to assure a correct lateral performance of the pump.

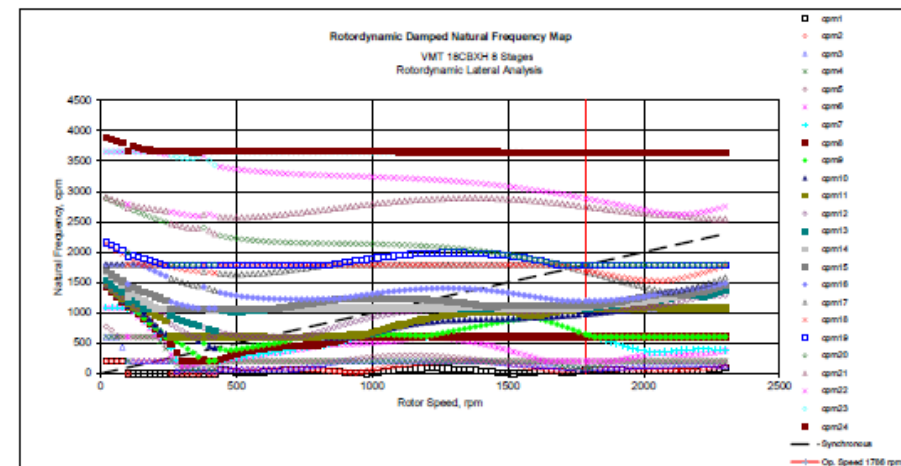


Figure 2: Lateral Campbell Diagram, As-New Clearances, With Water.

4A- Rotodynamic Lateral Analysis

RP format analysis simple (as provided to customer) :

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Table 4. Natural Frequencies, Damping Ratios, and Separation Margins at 1786 rpm.

Root	Shaft speed f_{run} (rpm)	Damping factor ζ	Natural frequency f_{ni} (cpm)	Separation margin sm_{res} (cpm)	Separation margin sm_{rel} (%)	Frequency ratio f_{ni}/f_{run}	Whirling	Type
cpm1	1786	1.000	74.8	1711.2	95.8	0.042	Forward	Rotor
cpm2	1786	1.000	77.2	1708.8	95.7	0.043	Forward	Rotor
cpm3	1786	1.000	82.9	1703.1	95.4	0.046	Backward	Rotor
cpm4	1786	0.999	98.2	1687.8	94.5	0.055	Backward	Rotor
cpm5	1786	0.001	203.9	1582.1	88.6	0.114	Backward	Rotor + Structure
cpm6	1786	0.001	204.0	1582.0	88.6	0.114	Forward	Rotor + Structure
cpm7	1786	0.128	605.2	1180.8	66.1	0.339	Forward	Rotor + Structure
cpm8	1786	0.130	605.3	1180.7	66.1	0.339	Backward	Rotor + Structure
cpm9	1786	0.965	653.3	1132.7	63.4	0.366	Backward	Rotor
cpm10	1786	0.324	977.7	808.3	45.3	0.547	Forward	Rotor
cpm11	1786	0.607	1070.0	716.0	40.1	0.599	Forward	Rotor
cpm12	1786	0.270	1076.2	709.8	39.7	0.603	Backward	Rotor + Structure
cpm13	1786	0.269	1077.3	708.7	39.7	0.603	Forward	Rotor + Structure
cpm14	1786	0.729	1091.3	694.7	38.9	0.611	Forward	Rotor
cpm15	1786	0.566	1133.6	652.4	36.5	0.635	Forward	Rotor
cpm16	1786	0.620	1195.6	590.4	33.1	0.669	Forward	Rotor
cpm17	1786	0.783	1680.8	105.2	5.9	0.941	Backward	Rotor
cpm18	1786	0.649	1706.2	79.8	4.5	0.955	Forward	Rotor
cpm19	1786	0.015	1788.9	2.9	0.2	1.002	Forward	Rotor + Structure
cpm20	1786	0.012	1789.4	3.4	0.2	1.002	Backward	Rotor + Structure
cpm21	1786	0.532	2749.2	963.2	53.9	1.539	Forward	Rotor
cpm22	1786	0.563	2883.4	1097.4	61.4	1.614	Backward	Rotor
cpm23	1786	0.019	3635.4	1849.4	103.5	2.035	Backward	Rotor + Structure
cpm24	1786	0.024	3639.5	1853.5	103.8	2.038	Forward	Rotor + Structure

Note: $sm_{rel} = sm_{res}/f_{run}$

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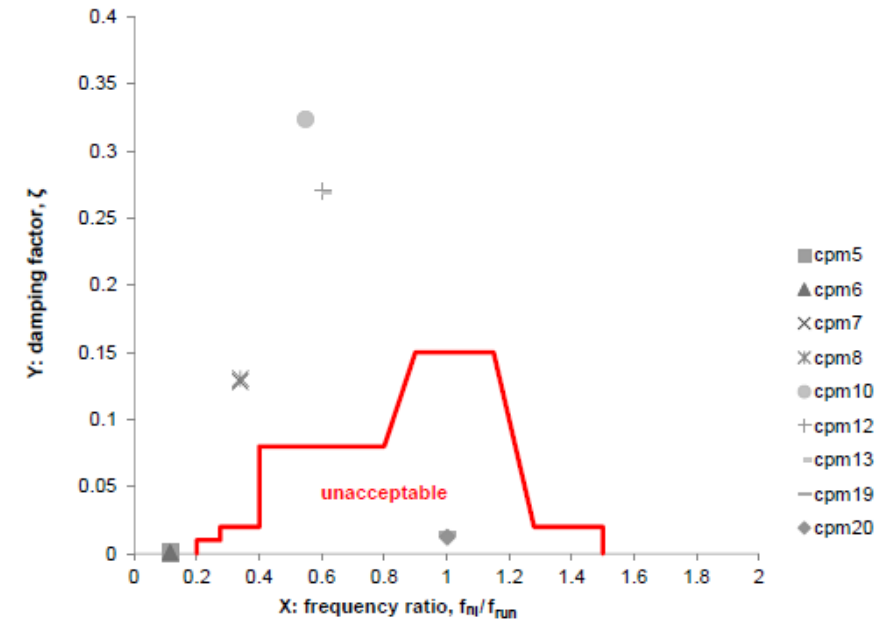


Figure 3. Damping Factor Versus Frequency Ratio, As-New Clearances, With Water.

As can be seen in Figure 3, two natural frequencies fall inside the "unacceptable" region established in API 610, 12th Edition, due to their damping ratios and separation margins.

The next step is to obtain the rotor damped response to unbalance and verify that the peak-to-peak displacement of the unbalanced rotor at the point of maximum displacement does not exceed 35% of the diametral running clearance at that point. Section 3.3.3 shows the Damped Unbalance Response Analysis.

4A- Rotodynamic Lateral Analysis

RP format analysis simple (as provided to customer) :

	VMT 18CBXH 8 Stages - Rotodynamic Lateral Analysis	BLB-RP0125 28-10-2025 Rev. 1
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4. Conclusions

With the assumed loads and considerations previously stated on this report, the following conclusions are presented:

1. According to API 610, 12th Edition, some rotor bending natural frequencies were found to be within the "unacceptable" region specified in Annex I, Figure I.1 of API 610, 12th Edition, for the following cases: as-new clearances with water, as-new clearances with the pumped fluid, and 2x (two times) the as-new clearances with the pumped fluid. A damped unbalance response analysis was performed for the "unacceptable" natural frequency, for each of these cases. The critical internal running clearance locations were inspected, which are mainly the bearings and annular seals. All the maximum peak-to-peak amplitudes in these pump internal clearances resulted to be less than 35% of the diametral running clearance at their respective locations. Thus, this requirement is fulfilled for the as-new clearances with water, as-new clearances with the pumped fluid and 2x (two times) the as-new clearances with the pumped fluid.
2. The VMT 18CBXH 8 Stages pump is suitable from a lateral rotordynamics standpoint.

4B- Rotodynamic Torsional Analysis

4B- Rotodynamic Torsional Analysis

4B- Rotodynamic Torsional Analysis

What is it and why it is needed ?

Torsional analysis evaluates the **twisting vibration behavior of a rotating shaft system**, including pumps, couplings, gears, and drivers. Unlike lateral analysis, which examines bending, torsional analysis focuses on **rotor angular deflections and torque oscillations** along the shaft.

The purpose is to ensure the rotor system can safely transmit torque without resonance, excessive twist, or torsional vibration that could:

- Damage shafts
- Overload couplings
- Cause seal or bearing issues
- Induce fatigue failure

4B- Rotodynamic Torsional Analysis

Why It Is Needed

Torsional vibration can occur due to:

- Engine or motor torque pulsations
- Impeller blade interactions with fluid
- Gear, turbine, or driver torque oscillations
- Startup and shutdown transients

Without torsional analysis:

- Shafts can resonate at critical torsional speeds
- Couplings may fail due to torque peaks
- Gears or timing components may overload
- Equipment may experience premature fatigue

4B- Rotodynamic Torsional Analysis – API 610 Requirements

6.9.2.2 An undamped natural frequency analysis shall be performed by the manufacturer having unit responsibility if any of the following describe the machinery train:

- a) multiple couplings: trains comprised of three or more coupled machines rated 2000 hp (1500 kW) or higher;
- b) gears: induction motors, or turbines, through gear rated 2000 hp (1500 kW) or higher;
- c) internal combustion engines: trains with engines rated 335 hp (250 kW) or higher;
- d) synchronous motors: trains with synchronous motors rated 670 hp (500 kW) or higher;
- e) ASDs rated 1350 hp (1000 kW) or higher;
- f) vertically suspended pumps: with a drivers rated 1000 hp (750 kW) or larger;
- g) induction motors: trains with induction (asynchronous) motors rated 2000 hp (1500 kW) or higher.

4B- Rotodynamic Torsional Analysis – API 610 Requirements

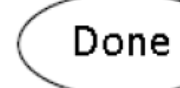


Figure 29—Torsional Analysis Flow Chart

4B- Rotodynamic Torsional Analysis

What is customer's benefit ?

Prevents Shaft and Coupling Failures

Avoids catastrophic rotor twisting and fatigue.

- Extends Equipment Life
 - Reduces stress on bearings, seals, and couplings.
- Ensures Safe Startup/Shutdown
 - Prevents resonance during speed ramps or transient torque events.
- Reduces Maintenance Costs
 - Minimizes unplanned downtime caused by torsional fatigue or shaft failure.
- Compliance with Standards
 - Meets API 610, API 617, and ISO/API torsional vibration requirements for pumps and rotating equipment.

What does it cost?

Indicative pricing - \$7,000 - \$11,000

4B- Rotodynamic Torsional Analysis

RP format analysis simple (as provided to customer)

	VMT 18CBXH 8 Stages – Rotordynamic Torsional Analysis	IMM-RP0020 09-07-2025
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3. Torsional analysis

3.1 Rotor model

The complete shaft train was modelled with 230 stations using CADRotor™ along with XLRotor™ code. Each shaft was modelled by means of axisymmetric elements. Impellers and other important non-negligible inertias were modelled as disks, added to the corresponding shaft at their respective center of gravity axial locations. The polar inertia of the impellers was provided by Ruhrpumpen. These values were then modified to take into account 60% of the entrained fluid the series impellers, which according to Nordmann [6], it is the appropriate factor to account for fluid effects in these impellers.

Modeling of the motor rotor and the flexible coupling was performed according to information provided directly from the motor and coupling vendors, respectively. The motor rotor's core inertia was added to the train model as three equally-spaced lumped inertias.

The detail of the rotor model is shown in Figure 1.

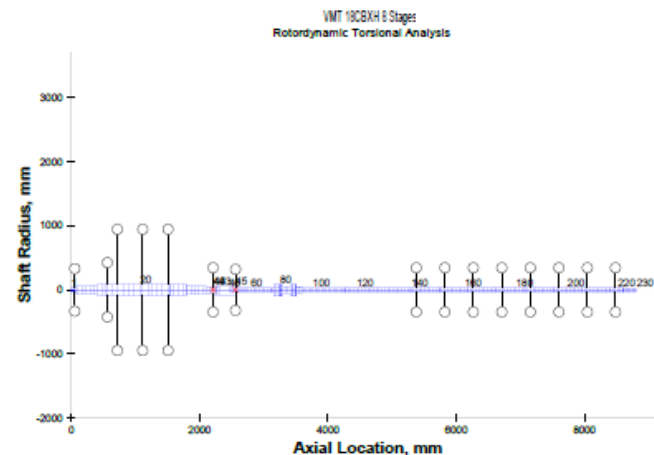


Figure 1. Rotor model for torsional analysis.

	VMT 18CBXH 8 Stages – Rotordynamic Torsional Analysis	IMM-RP0020 09-07-2025
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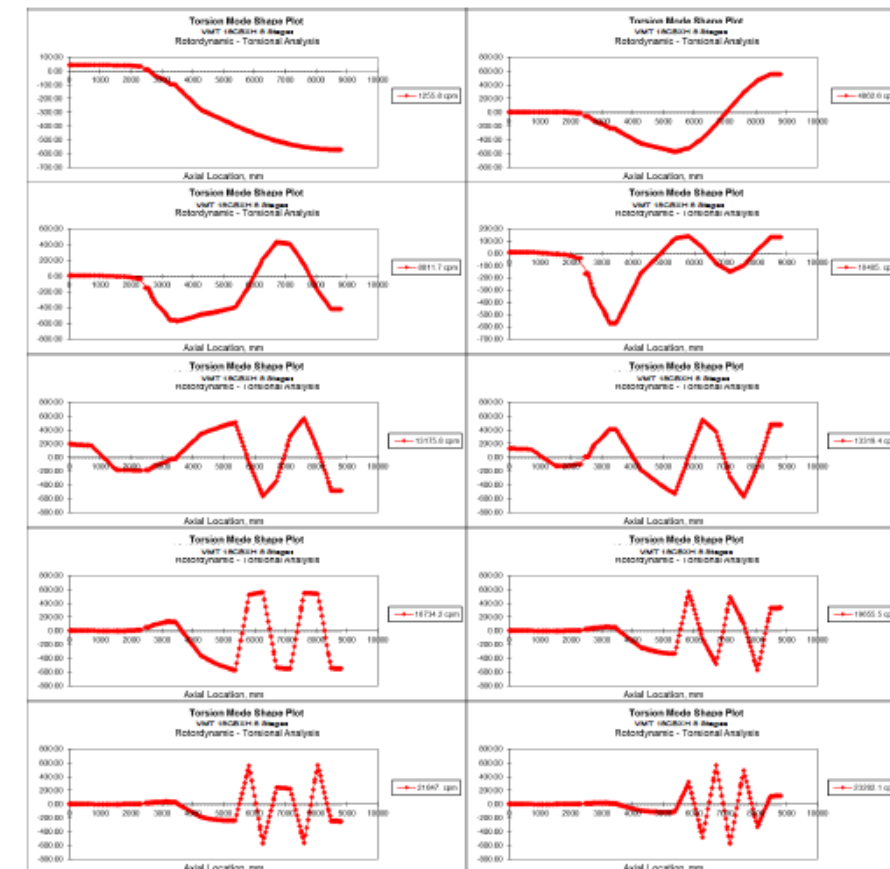


Figure 2. Torsional mode shapes plots.

4B- Rotodynamic Torsional Analysis

RP format analysis simple (as provided to customer)

	VMT 18CBXH 8 Stages – Rotordynamic Torsional Analysis	IMM-RP0020 09-07-2025
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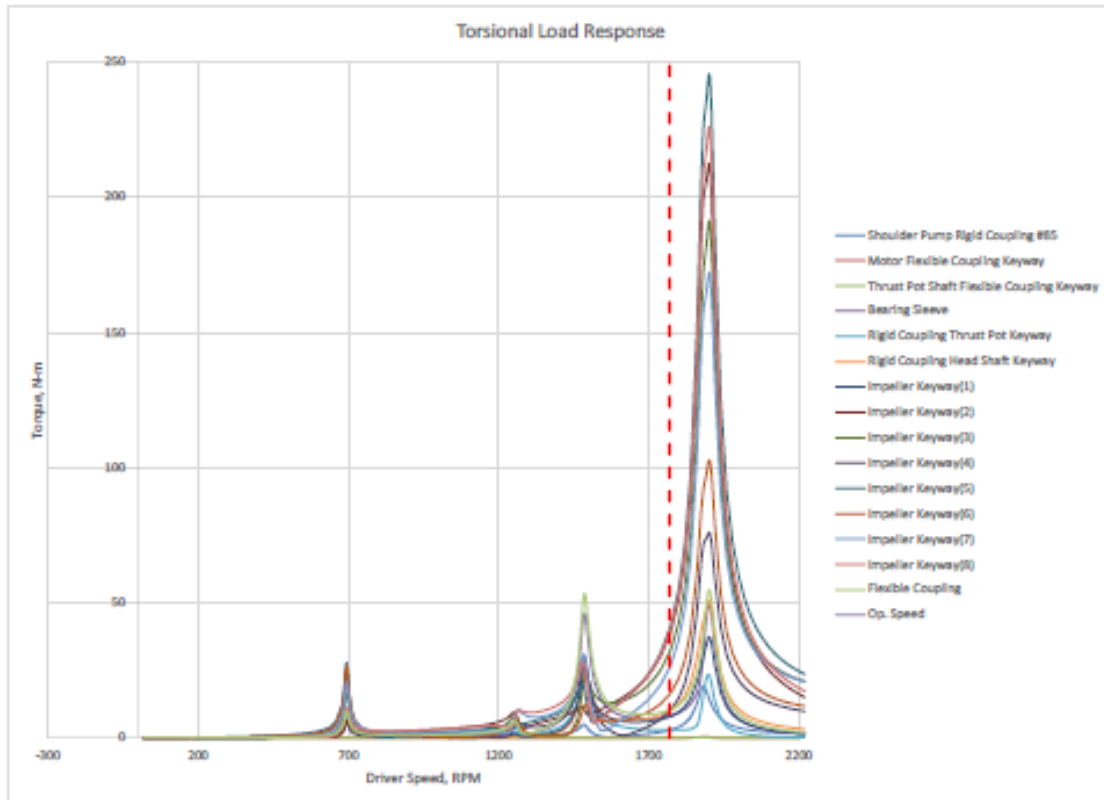


Figure 7. Torsional load response vs reference speed (order 7x – Mode 6).

	VMT 18CBXH 8 Stages – Rotordynamic Torsional Analysis	IMM-RP0020 09-07-2025
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4. Conclusions

With the assumed loads and considerations previously stated on this report, the following conclusions are presented:

1. According to API 610, 12th Edition, the torsional analysis of the VMT 18CBXH 8 Stages pump identified four interference points on the Campbell diagram within the $\pm 10\%$ separation margins of the operating speed. Some of these interference points were discarded based on their mode shapes. For the remaining interference points, a steady-state damped response analysis was performed, and the cyclic torques and shear stresses were calculated for each critical region, which mainly consist of keyways. These cyclic torques and shear stresses were then used to calculate the fatigue safety factors for each critical region. All calculated fatigue safety factors were greater than 2.0, which is the value recommended by experts in the field of torsional vibration. Therefore, the identified interference points are considered acceptable.
2. The flexible coupling is within acceptable limits and can be considered suitable for the current operating conditions.

The VMT 18CBXH 8 Stages pump is suitable for operation from a torsional rotodynamic perspective.

The results presented in this report are only valid under the considerations and criteria previously described.

4C- Rotodynamic Transient Torsional Analysis

4C- Rotodynamic Transient Torsional Analysis

4C- Rotodynamic Transient Torsional Analysis

What is it and why it is needed ?

What It Is

Transient torsional analysis evaluates the **time-dependent twisting behavior of a rotor system** during **non-steady conditions**, such as:

- Startup
- Shutdown
- Load changes
- Emergency trips (e.g., fast shutdown of turbines or motors)

Unlike steady-state torsional analysis, which only looks at **natural frequencies and forced steady vibration**, transient torsional analysis predicts:

- Shaft angular acceleration and deceleration
- Time-varying torque distribution along the shaft
- Peak torsional stress and twist during transients
- Coupling and gear torque limits

This is critical for ensuring rotor safety during extreme operating events.

4C- Rotodynamic Transient Torsional Analysis

Why It Is Needed

During transient events, shafts and couplings can experience **torque spikes** that exceed allowable limits:

- Rapid motor startup may excite torsional modes
- Fast turbine trip may cause reverse torque or shaft twist
- Load rejection can create torque reversals or high stress on flexible couplings
- Misalignment or inertia differences between driver and pump can amplify torsional vibration

Without transient analysis:

- Shafts or couplings may fail catastrophically
- Bearings and seals may be overloaded
- Vibration-induced fatigue may reduce service life

What does it cost?

Indicative pricing - \$3,000 - \$4,000

4B- Rotodynamic Torsional Analysis – API 610 Requirements

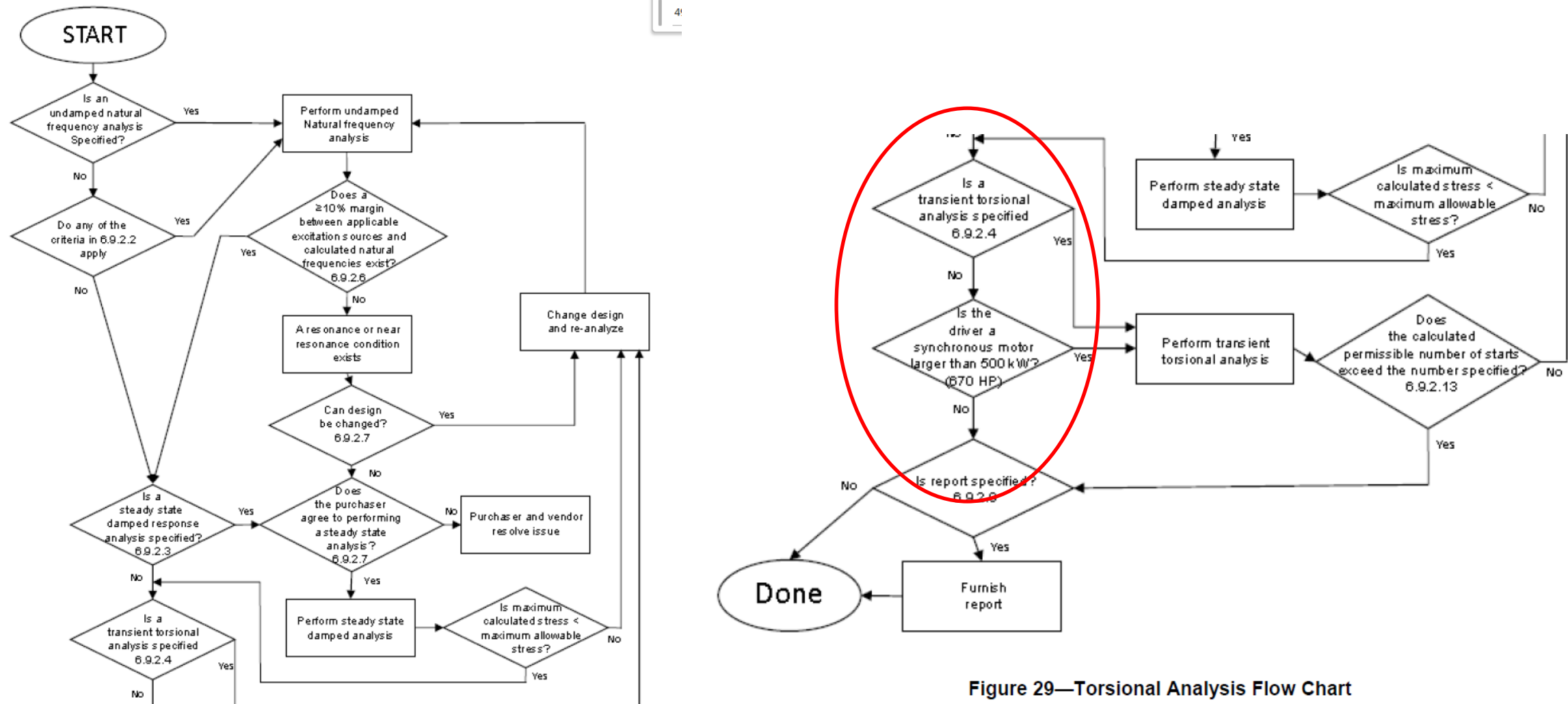


Figure 29—Torsional Analysis Flow Chart

4C- Rotodynamic Transient Torsional Analysis

What is customer's benefit ?

- Prevents Shaft and Coupling Damage
Avoids over-torque during startup/shutdown and emergency events.
- Extends Rotor and Equipment Life
Reduces fatigue and stress on bearings, seals, and couplings.
- Safe Operation During Transients
Ensures pump and motor or turbine operate safely under rapid changes.
- Compliance with Standards
Supports API 610, API 617, and ISO/API torsional vibration requirements for transient conditions.
- Reduced Maintenance and Downtime
Prevents catastrophic failure and unplanned shutdowns.

4C- Rotodynamic Transient Torsional Analysis

RP format analysis simple (as provided to customer)

	ZMS II 680/06 x 2 (A) – Rotordynamic Transient Torsional Analysis	JVO-RP0078 21-10-2025
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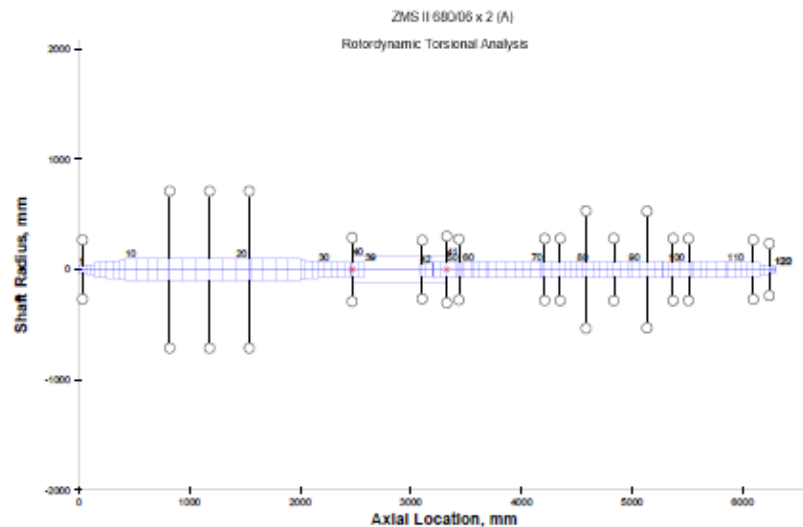


Figure 1. Rotor model for transient torsional analysis.

	ZMS II 680/06 x 2 (A) – Rotordynamic Transient Torsional Analysis	JVO-RP0078 21-10-2025
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3.3.5 Results

Peak response torques are listed in Table 5 for the shaft weakest regions at the eleven different transient conditions.

Table 6. Peak transient response load.

Station	Peak torques (kN-m)			
	Start-Up	Line-to-Line Short Circuit	Three-Phase Short Circuit	Phase Opposition Reclosing Reaction
Motor Shoulder, Station #5	0.4962	1.2153	0.8455	1.9126
Motor Shoulder, Station #9	0.5504	1.3266	0.9378	2.1226
Motor Shoulder, Station #27	14.2022	29.7310	31.8078	63.6144
Connection Coupling Motor	14.2342	29.8180	31.9117	63.8415
Connection Coupling Pump	13.9038	29.4971	31.6405	63.1788
Impeller Nut DE, Keyway	13.7556	29.2660	31.3949	62.6210
Impeller 2nd Stage, Keyway	13.5813	25.7265	28.0029	59.5129
Throttling Sleeve, Keyway	7.1500	15.1252	16.2992	32.6660
Suction Impeller, Keyway	0.3799	0.7839	0.8740	1.7662
Impeller Nut NDE, Keyway	0.1667	0.3440	0.3835	0.7751
Fan, Keyway	0.0002	0.0005	0.0005	0.0010

3.4 Stress-Life Fatigue Analysis

Stress life fatigue assessment was performed for each critical shaft region at every transient event in order to determine the number of starts of short circuits that the ZMS II 680/06 x 2 (A) pump can be subjected to.

XLRotor code was used for this calculation. This calculation is based on the Goodman adjustment fatigue life assessment and the Miner's rule for cumulative fatigue damage. If number of starts is 1000000 and number of cycles in life calculation is equal to 0, then the shaft's analyzed station has an infinite number of life cycles or starts. On the other hand, if the number of starts is 0, then shaft is not acceptable for the peak torques calculated previously.

4C- Rotodynamic Transient Torsional Analysis

RP format analysis simple (as provided to customer)

	ZMS II 680/06 x 2 (A) – Rotordynamic Transient Torsional Analysis	JVO-RP0078 21-10-2025
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Table 10. Stress life calculation, Phase Opposition Reclosing Reaction.

	Component Name	Motor Shoulder, Shaft 1	Motor Shoulder, Shaft 2	Motor Shoulder, Shaft 3	Connection Coupling, Motor	Connection Coupling, Pump	Impeller Hub CR, Motor	Impeller Hub CR, Pump	Thrusting Sleeve, Motor	Radial Impeller, Motor	Impeller Hub CR, Pump	Shaft, Motor
		COGN LINE IN 1000L1	COGN LINE IN 1000L1	COGN LINE IN 1000L1	COGN LINE IN 1000L1	COGN LINE IN 1000L1	A 1000L1, PUMP	A 1000L1, PUMP	A 1000L1, PUMP	A 1000L1, PUMP	A 1000L1, PUMP	A 1000L1, PUMP
INPUTS	Material	30	30	30	30	30	30	30	30	30	30	30
	Stress Cycle, Discrete	0	0	0	0	0	0	0	0	0	0	0
	Stress Cycle, Discrete	0	0	0	0	0	0	0	0	0	0	0
	Thermal Stress Conversion Factor, Is	2.446421200	2.446421200	2.120004000	2.4	2.4	4.021	4.021	4.021	4.021	4.021	3.000111111
	Ultimate Tensile Strength, Is	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08
	Yield Strength, Is	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Radial Stress Factor, Is	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000
	Stress Factor, Is	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Load Factor, Is	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Temperature Factor, Is	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Radial Stress Factor, Is	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Radial Stress Factor, Is	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Radial Stress Factor, Is	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Radial Stress Factor, Is	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
OUTPUTS	Rate of 1000 Cycle Limit Is (Ultimate Is)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Rate of 1000 Cycle Limit Is (Ultimate Is)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Radial Stress Factor, Is (1000L1)	2.120004000	2.120004000	1.000000000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000
	Ultimate Tensile Strength, Is	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08	5.02E+08
	1000 Cycle Mean Radial Stress	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000
	1000 Cycle Mean Radial Stress	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000
	1000 Cycle Mean Radial Stress	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000
	1000 Cycle Torque Limit	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000
	1000 Cycle Torque Limit	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000
	Torque at 1000L1	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000	0.000100000
	Life in number of cycles	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000	1000000
	Number of cycles in 1000L1	0	0	0	0	0	0	0	0	0	0	0

4C- Rotodynamic Transient Torsional Analysis

RP format analysis simple (as provided to customer)

4. Conclusions

With the assumed loads and considerations previously stated on this report, the following conclusions are presented:

1. Transient torsional analysis was performed on the ZMS II 680/06 x 2 (A) pump shaft train, using stress life calculation method. For the eight transient cases analyzed, all stations of interest obtained way over 1500 starts, which is the recommended API number of starts for driven equipment, thus, this requirement is fulfilled.
2. The ZMS II 680/06 x 2 (A) pump is adequate to operate from a transient torsional rotordynamics standpoint.



Coming Attractions 😊

“New Developments in the VS6 Market”
(vertical double case pumps for low NPSH service)

Thurs 19th February 2026 – 08.00 (UK GMT) (Eastern Hemisphere) & 17.00 (UK GMT) (Western Hemisphere)

Vertical pumps, especially VS6 pumps, are among the least well understood pump types among rotating equipment engineers, mainly because they are not as frequently used as their horizontal brothers. This short course will revisit VS6 & VS1 pumps in API610 hydrocarbon applications and introduce an exciting new development in this market segment.

Aimed at Process and Mechanical Engineers, and Consultant Engineers who specify pumping equipment as well as Applications & Sales Engineers selecting and quoting them



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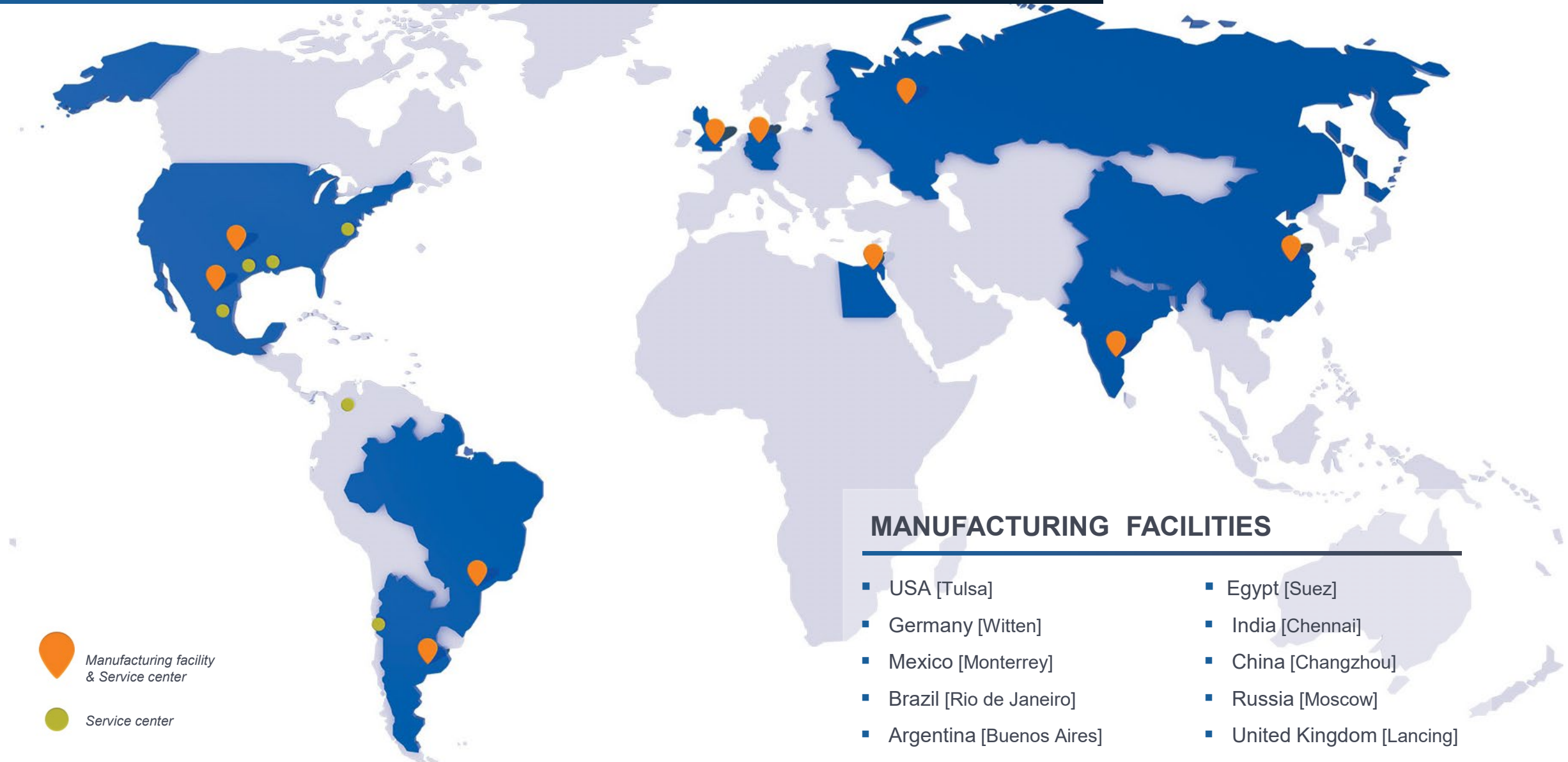
**+70 YEARS
OF EXPERIENCE**

**+2,000
EMPLOYEES**

**15 SERVICE
CENTERS**

+70,000 PUMPING SOLUTIONS INSTALLED WORLDWIDE

A GLOBAL COMPANY





MANUFACTURING FACILITIES

Monterrey, MX



Area: 18,000 m²
Testing: 7,500 HP

Tulsa, USA



Area: 29,000 m²
Testing: 2,000 HP

Witten, DE



Area: 48,000 m²
Testing: 8,850 HP

Changzhou, CN



Area: 15,000 m²
Testing: 6,000 HP

Lancing, UK



Area: 1,703 m²
Testing: 670 HP

Rio de Janeiro, BR



Area: 7,500 m²
Testing: 6,000 HP

Buenos Aires, AR



Area: 7,500 m²
Testing: 1,500 HP

Suez, EG



Area: 2,280 m²
Testing: 2,680 HP

Chennai, IN



Area: 11,000m²
Testing: 6,000 HP

MARKETS WE SERVE

Our commitment to create innovations that offer reliable solutions to our customers allow us to provide a complete range of pump systems to support **core markets** as:





OUR PUMP LINES

Ruhrpumpen offers a broad range of highly engineered and standard pumping products that meet and exceed the requirements of the most demanding quality specifications and industry standards.

Our pumps can handle head requirements as high as 13,000 ft (4,000 m) and capacities up to 300,000 gpm (68,000 m³/hr). Moreover, our pump designs cover temperatures from cryogenic temperatures of -310 °F (-196 °C) up to 752 °F (400 °C).

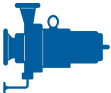
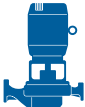
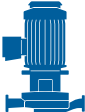


Products include:

- Single Stage Overhung Pumps
- Between Bearings Pumps
- Horizontal Multi-Stage Pumps
- Vertical Multi-Stage Pumps
- Vertical Mixed Flow & Axial Flow Pumps
- Positive Displacement Pumps
- Full Range of Industrial Pumps
- Submersible Pumps
- Magnetic Drive Pumps
- Decoking Systems
- Packaged Systems
- Fire Systems



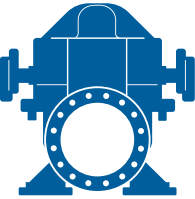
OVERHUNG PUMPS

CATEGORY	RP MODEL	DESIGN STANDARD	
Sealless Magnetic Drive Pumps	CRP-M / CRP-M-CC	ISO 2858 & 15783 HI design (OH11)	
	SCE-M	API 685	
Foot Mounted OH1 and General End Suction Pumps	IPP	HI design (OH1)	
	CPP / CPP-L	HI design (OH1) ANSI B73.1	
	CPO / CPO-L	HI design (OH1) ANSI B73.1	
	CRP	HI design (OH1) ISO 2858 & 5199	
	GSD	HI design (OH0)	
	SHD / ESK / SK / SKO SKV / ST / STV	HI design (OH1)	
	SWP	HI design (OH3A)	
Centerline Mounted	SCE	API 610 (OH2)	
Vertical In-Line Pumps	SPI	API 610 (OH3)	
	IVP / IVP-CC	HI design (OH4 / OH5)	
	IIL	HI design (OH5) Dimensionally compliant with ANSI B73.2	
	SPN	API 610 (OH5)	





BETWEEN BEARING PUMPS

CATEGORY		RP MODEL	DESIGN STANDARD	
1 and 2 stage	Axially split	HSC / HSD / HSL HSR / ZW	HI design (BB1)	
		HSM	HI design (BB3)	
		ZM / ZMS ZLM / ZME	API design (BB1)	
	Radially split	HVN / J	API design (BB2)	
		RON / RON-D	API design (BB2)	
Multi-stage	Axially split	SM / SM-I	API design (BB3)	
		JTN	API design (BB3)	
	Radially split <i>single casing</i>	GP	API design (BB4)	
	Radially split <i>double casing</i>	A LINE	API design (BB5)	





VERTICAL PUMPS

CATEGORY		RP MODEL	DESIGN STANDARD	
Single casing	Diffuser	VTP	HI & API 610 (VS1)	
		VCT	HI & API 610 (VS1)	
		HQ	HI & API 610 (VS1)	
		VLT	HI & API 610 (VS1)	
	Volute	DSV / DX	HI & API 610 (VS2)	
	Discharge through column – Axial flow	VAF	HI & API 610 (VS3)	
Double casing	Separate discharge line	VSP / VSP-Chem	HI & API 610 (VS4)	
	Diffuser	VLT / VMT	HI & API 610 (VS6)	
	Volute	DSV / DX	HI & API 610 (VS7)	
Submersible pumps		SMF	HI design (OH8A)	
		VLT-Sub / VTP-Sub	HI design (VS0)	





SPECIAL SERVICE PUMPS

CATEGORY	RP MODEL	DESIGN STANDARD	
Pitot tube pumps	COMBITUBE	HI design	
Reciprocating pumps	RDP	API 674 ISO 13710	
Vertical turbine generator	VTG	HI design (VS6)	
Barge	LS BARGE	HI design	
Floating dock pumps	ZVZ	HI design	
	LVZ	HI design	
Cryogenic pumps	SVNV	-	
	VTG Cryogenic	-	
	VLT Cryogenic VLTV	-	
Pre-packaged fire pump systems	Fire systems incorporate pumps, drivers, control systems and pipework in a single container. They can be skid mounted, with or without enclosure and supplied with electric motor or diesel engine.		 NFPA-20-850 UL and FM approved components

