2010 ANSYS SOUTH AMERICAN CONFERENCE
& ESSS USERS MEETING
October 19-22 - Atibaia, SP - Brazil

Centrifugal Pumps Mechanical Design
ANSYS analysis Vibration in Vertical Pumps

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PRESENTATION PARTS

- Sulzer , Sulzer Pumps and Sulzer Pumps in Brazil
- Pumps and Vertical Pumps
- Case Study: Vertical Pump in VCP – 3 Lagoas MS
- Conclusion

Sulzer and Sulzer Pumps

Sulzer Pumps

Pumping solutions and services

Sulzer Metco

Surface technology solutions and services

Sulzer Chemtech

Components and services for separation columns and static mixing

Sulzer Turbo Services

Service and repair of thermal turbomachinery

Sulzer Innotec

Contract research and technical services

ESSS

Sulzer market

	Sulzer Pumps	Sulzer Metco	Sulzer Chemtech	Sulzer Turbo Services
 Oil and gas (incl. HPI, CPI, etc.)	■	■	■	■
 Pulp and paper	■	■	■	■
 Turbines and power generation	■	■	■	■
 Automotive		■	■	

ESSS

Sulzer Brasil - Jundiaí

Pattern Storage
- 1400m²

Office building
- 2500m²
- 2 stories

Factory
- 7200m²
- 5 bays
- 45t lifting cap.

Canteen

Component Machining
- 2000 m²

Foundry
- 3500 m²

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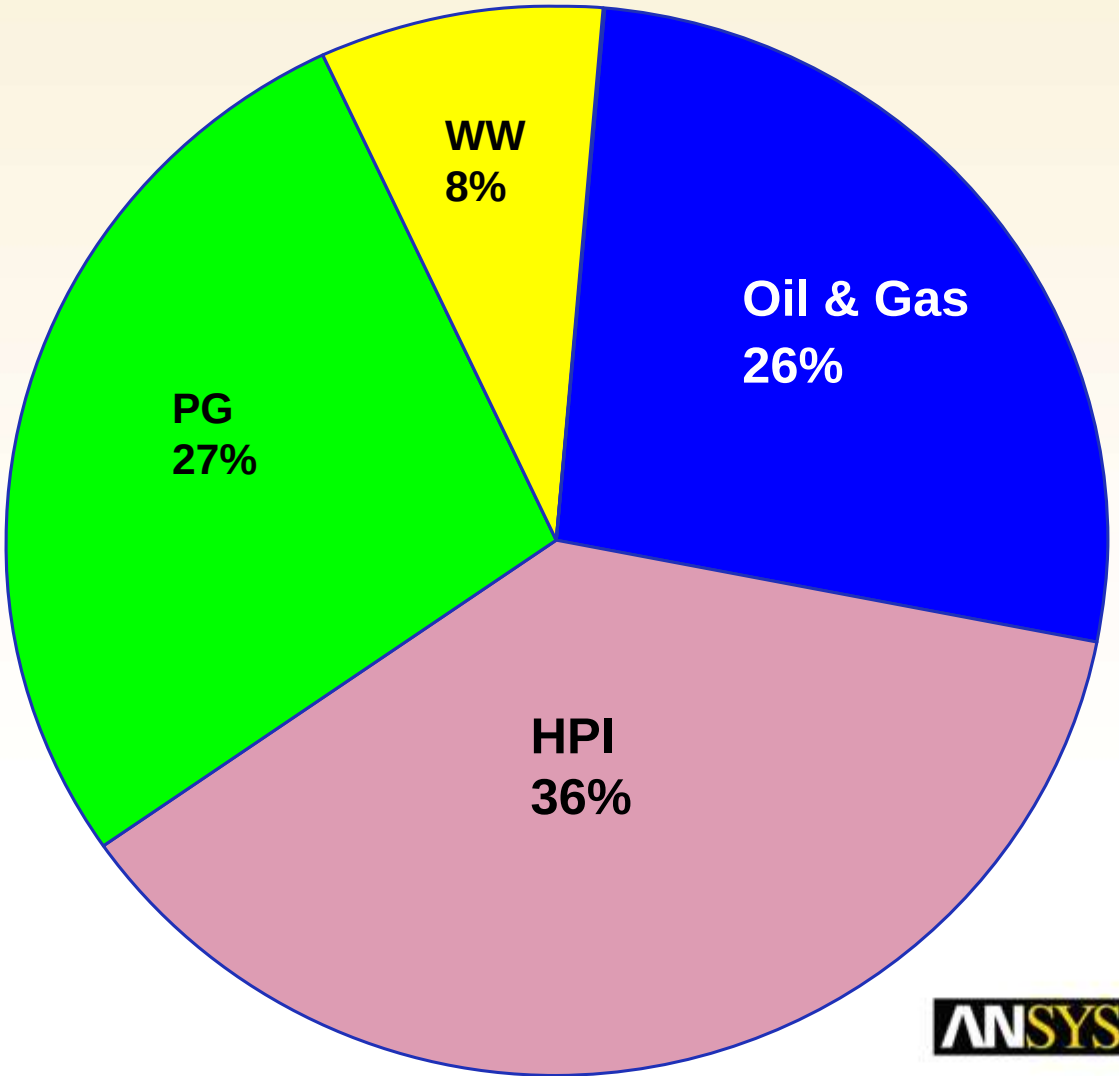
Sulzer Brasil - 2009



Orders received
New Pumps
360 BRL million

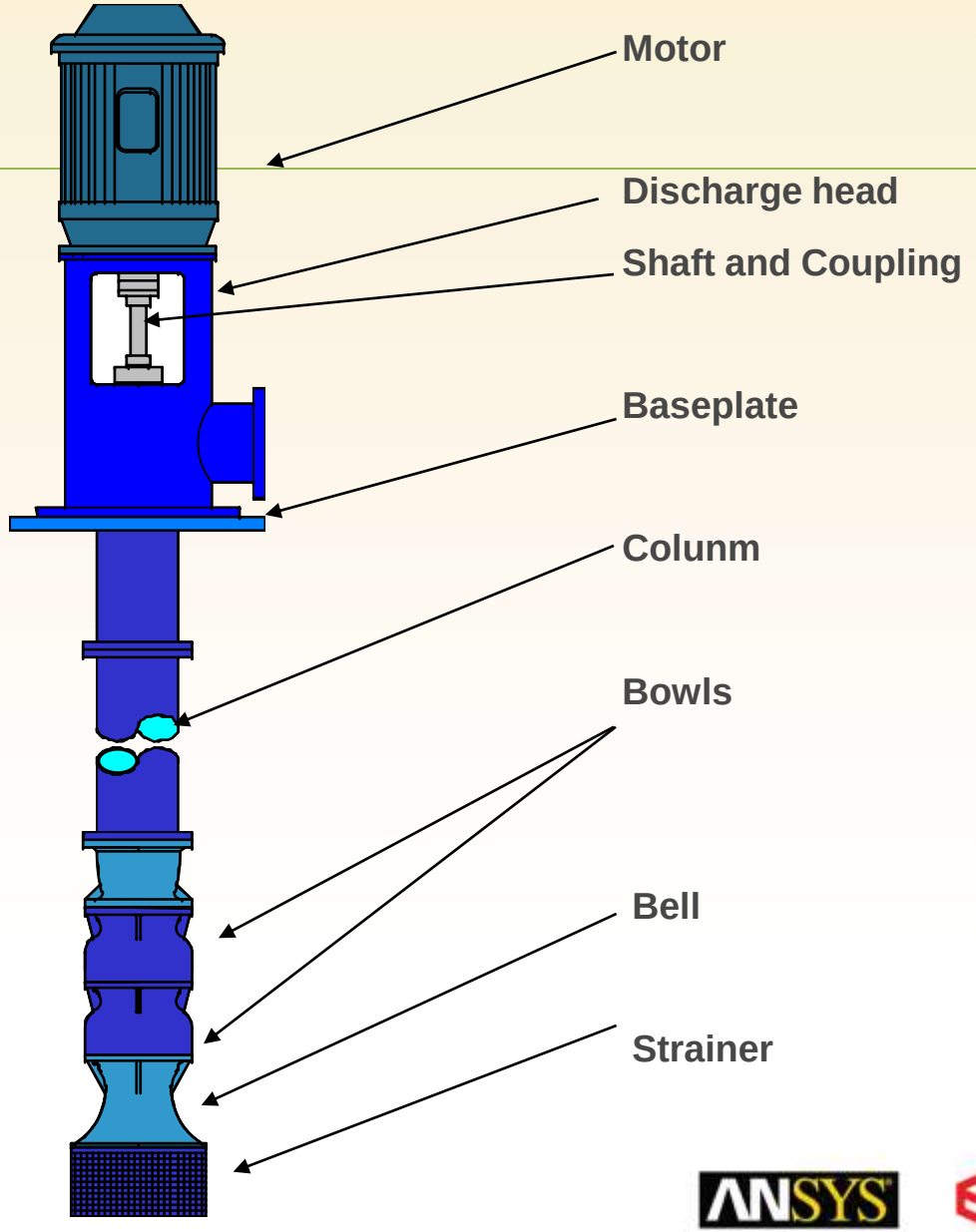
Sulzer Pumps Products – except Vertical

Overhung	*Horizontal*	*Foot Mounted*	***CPT, Z***
		Centerline Mounted	***CAP, OHH, OHL***
	Vertical	*In-Line*	***OHV***
		End-Suction	***ZAV***
Between Bearings	*1 & 2 stages*	*Axially Split*	***SMN, SMH, HSB, HPDM, ZPP***
		Radially Split	***BBT, BBS, BBT-D, CD, BBS-SC***
	Multistage	*Axially Split*	***MSD, MSE, MSD2***
		Radially Split- Single casing	***MBN, MC, MD, ME***
		Radially Split- Double Casing - Barrel	***GSG, CP, HPcp, HPT***

Sulzer Vertical Pumps

Single Casing	*Through Column*	*Diffuser*	***TMC BK, BKn, BSm SJT, SJM, JTS***
		Volute	***BSD***
		Axial Flow	***BPn SJP***
	Separate Discharge	*Line-shaft*	***ZN***
		Cantilever	***NKP***
Double Casing		*Diffuser*	***TTMC BKC, SJD VCR***
		Volute	***BDC***

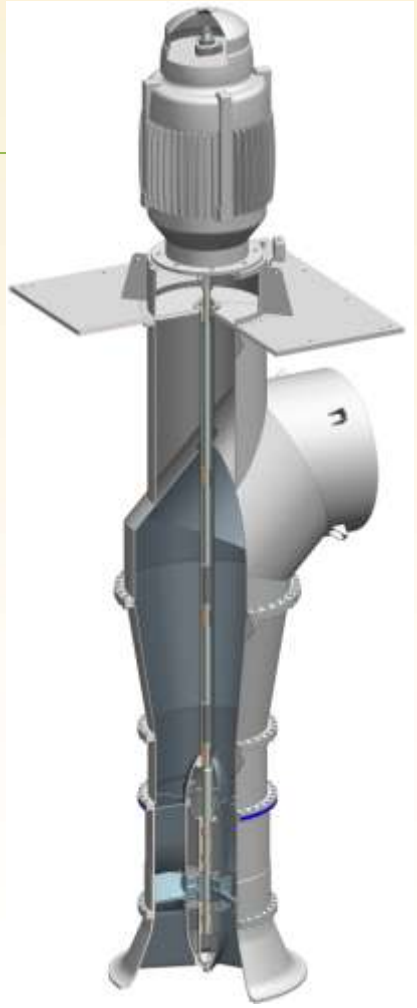
Sulzer
Vertical Pump



Sulzer Vertical Pumps – Main Types

SJT Turbine
Ns 1800 < 5000
nq 35 < 110

SJM Mixed Flow
Ns 5800 < 8300
nq 113 < 161



SJP Axial Flow
Ns ~ 14,500
nq ~ 280

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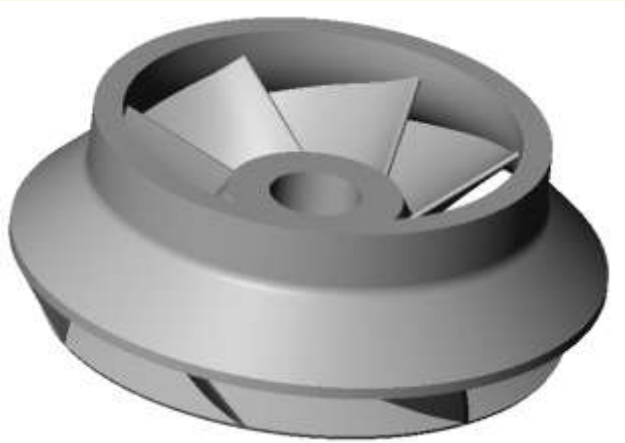
Vertical Pumps - Hydraulics

Impeller types



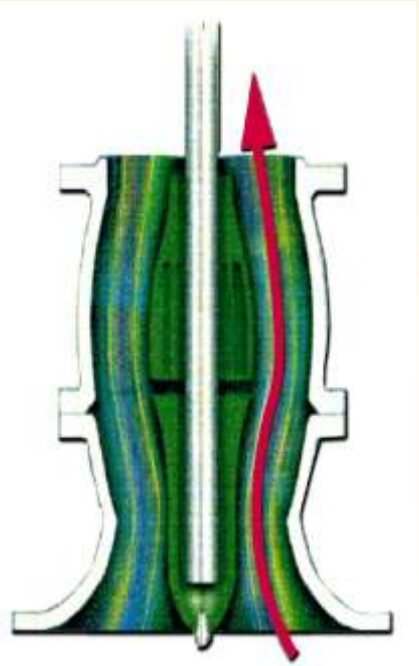
CLOSED

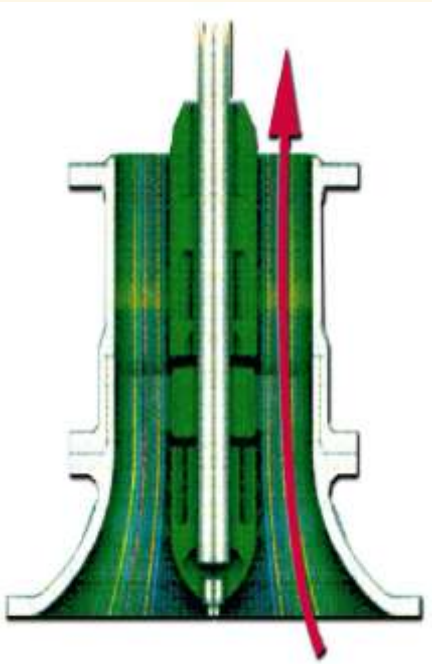
SEMI-CLOSED

OPEN

Vertical Pumps - Hydraulics

Turbine Mixed Axial

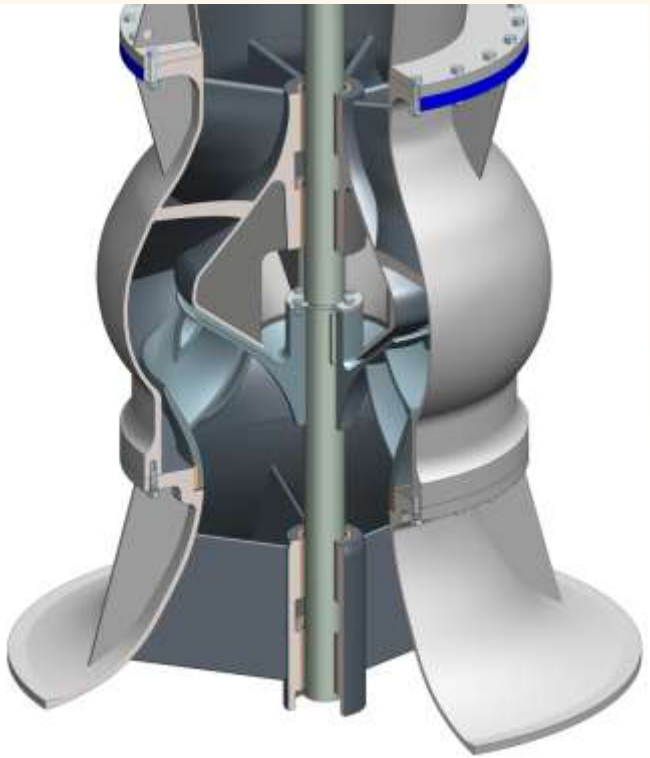




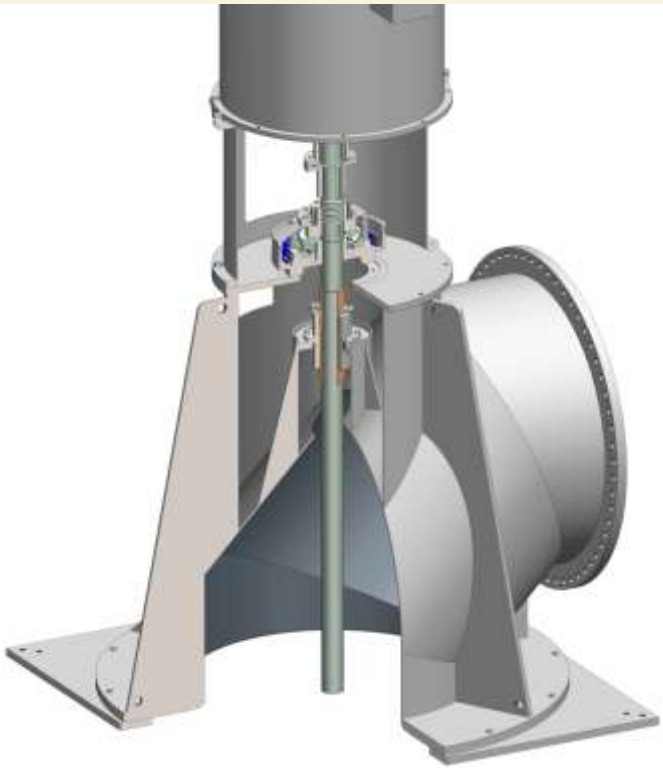
Types according to flow type

Sulzer Vertical Pumps – 3 main parts

SUCTION - BOWL

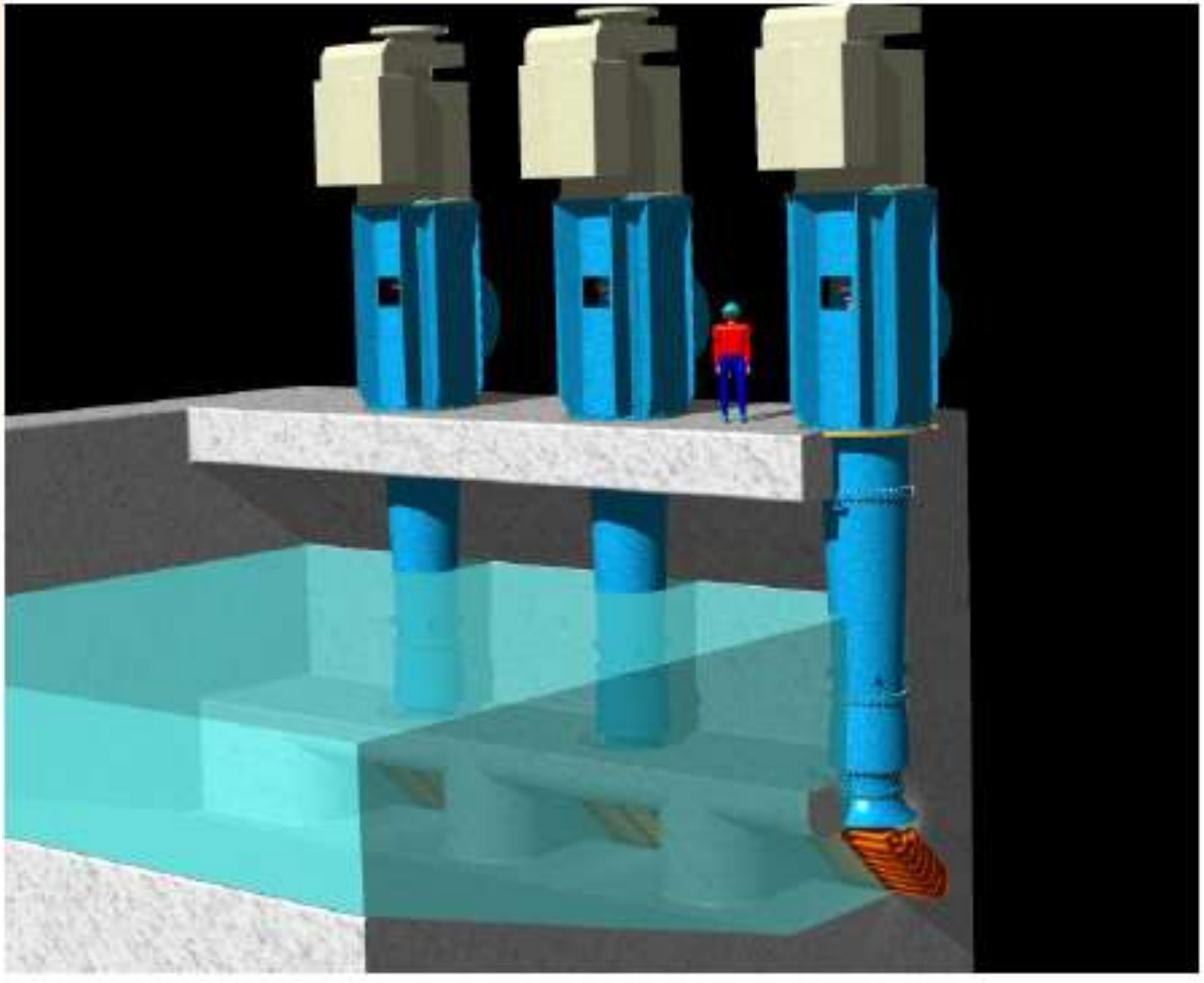


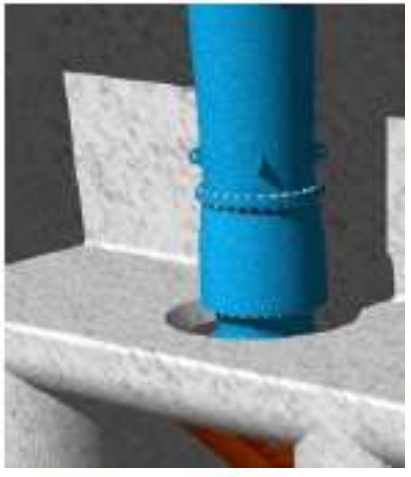
COLUMN



DISCHARGE HEAD

Vertical Pumps – Field Installation





Sulzer Vertical Pump – BSm at test

Cooling System

Sulzer Vertical Pump – BSm at field

BSm 1400-1s

36'000 m3/h at 14m

310 RPM, 1520 kW

Diam. Discharge

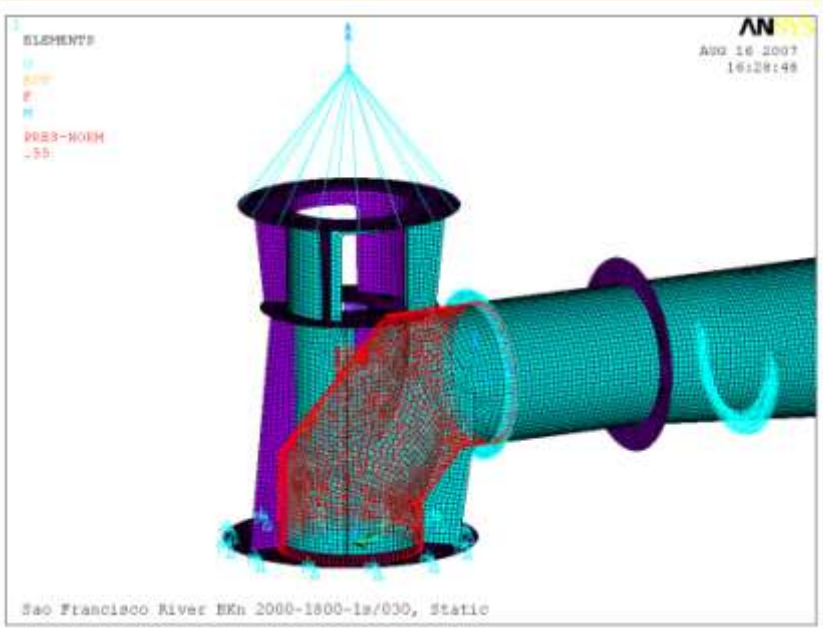
2000mm

Vertical Pump – Static Analysis

→ Example: São Francisco, BKn2000-1800-1s/030

Loads and Restraints:

- → Internal pressure, applied on "wet surface"
- → Pressure on "cover faces" is applied as equivalent axial force
- → Motor torque
- → Nozzle loads
- → Rotor mass at axial bearing
- → Restraints at bolt locations and pipe



Vertical Pump – Static Analysis

→ Example: São Francisco, BKn2000-1800-1s/030

Allowable Membrane Stress: $\sigma_{m,all} = \frac{R_{p,0.2}}{SF}$

- Primary Membrane Stress

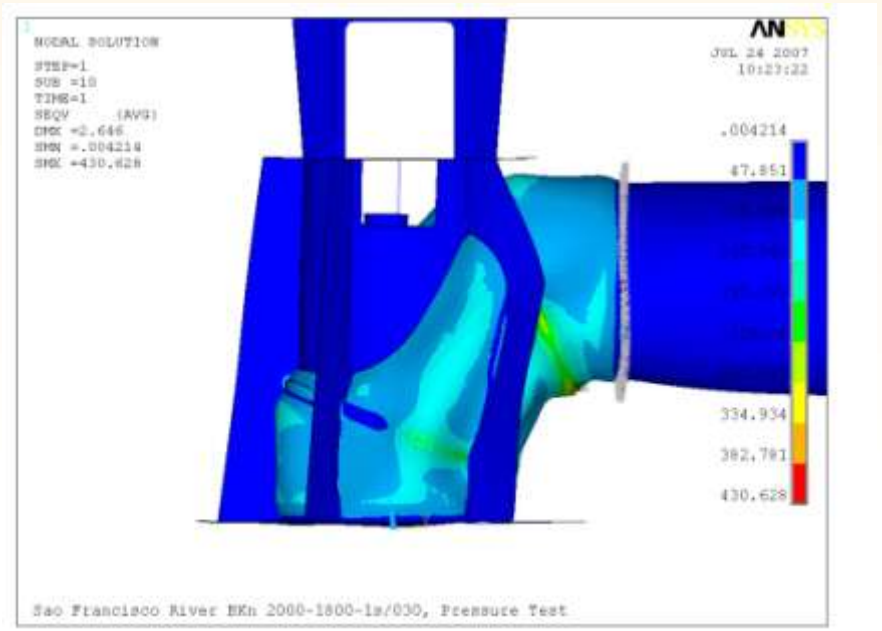
  $\sigma_{eq} \leq \sigma_{m,all}$

- Local Primary Membrane Stress

  $\sigma_{eq} \leq 1.5 \cdot \sigma_{m,all}$

- Secondary Membrane + Bending Stress

  $\sigma_{eq} \leq 3 \cdot \sigma_{m,all}$



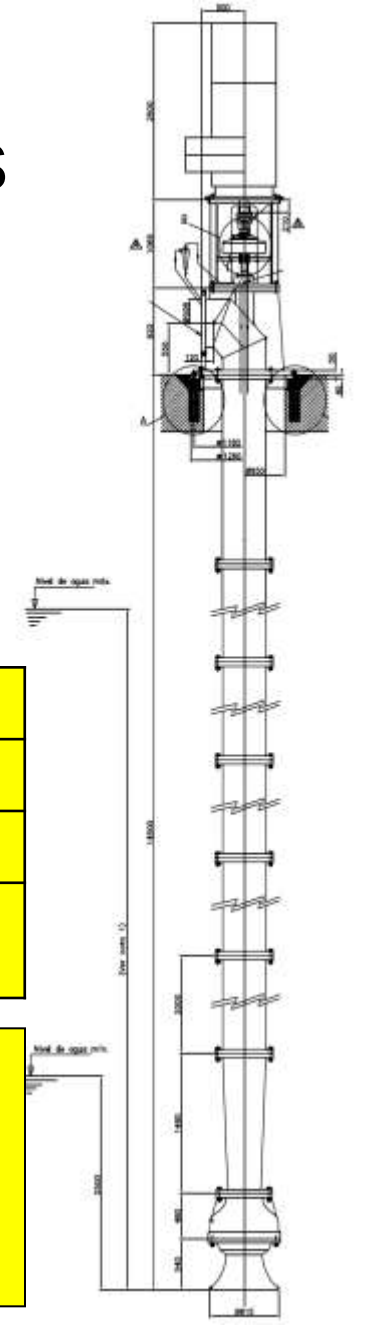
Case Study - Vertical Pump in 3 Lagoas

General Dimensions

D_{nom} = 508 [mm]
Height of Column Pipe = 14500 [mm]
Height of Motor Stool = 1985 [mm]
Height of Motor = 2500 [mm]
Total Height = 18985 [mm]

Pump Data

Geometry



Performance Data

Rated Flow	2218 [m^3/h]
Rated Head	49 [m]
Rated Speed	1186 [rpm]
Pumped Fluid	Water

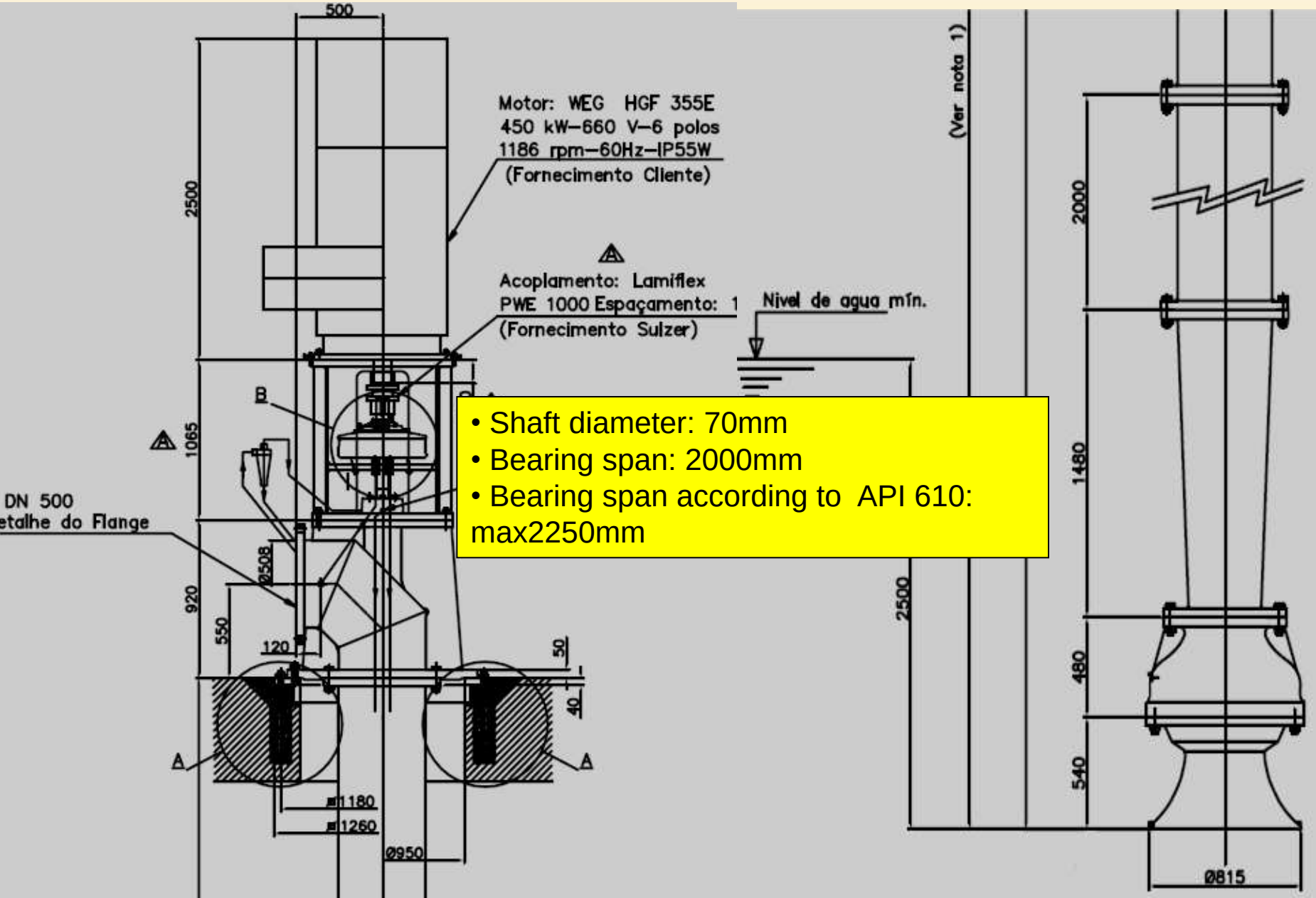
Masses and Inertias

Material Data

Pipes:	A36
Flanges:	A36
Motor Stool:	A36
Pump Bowl:	0.7040
Bellmouth:	0.6025

	m [kg]	I_p [kgm^2]	I_t [kgm^2]
Impeller	165.9	7.23	3.85
Motor	2'790	17.6	-
Axial Bearing	76.9	0.57	-

Other data
Impeller diameter: 567mm - nq 47
Weights (kg):
Pump: 5400 - Baseplate: 256
Motor: 2790 - Total: 8446

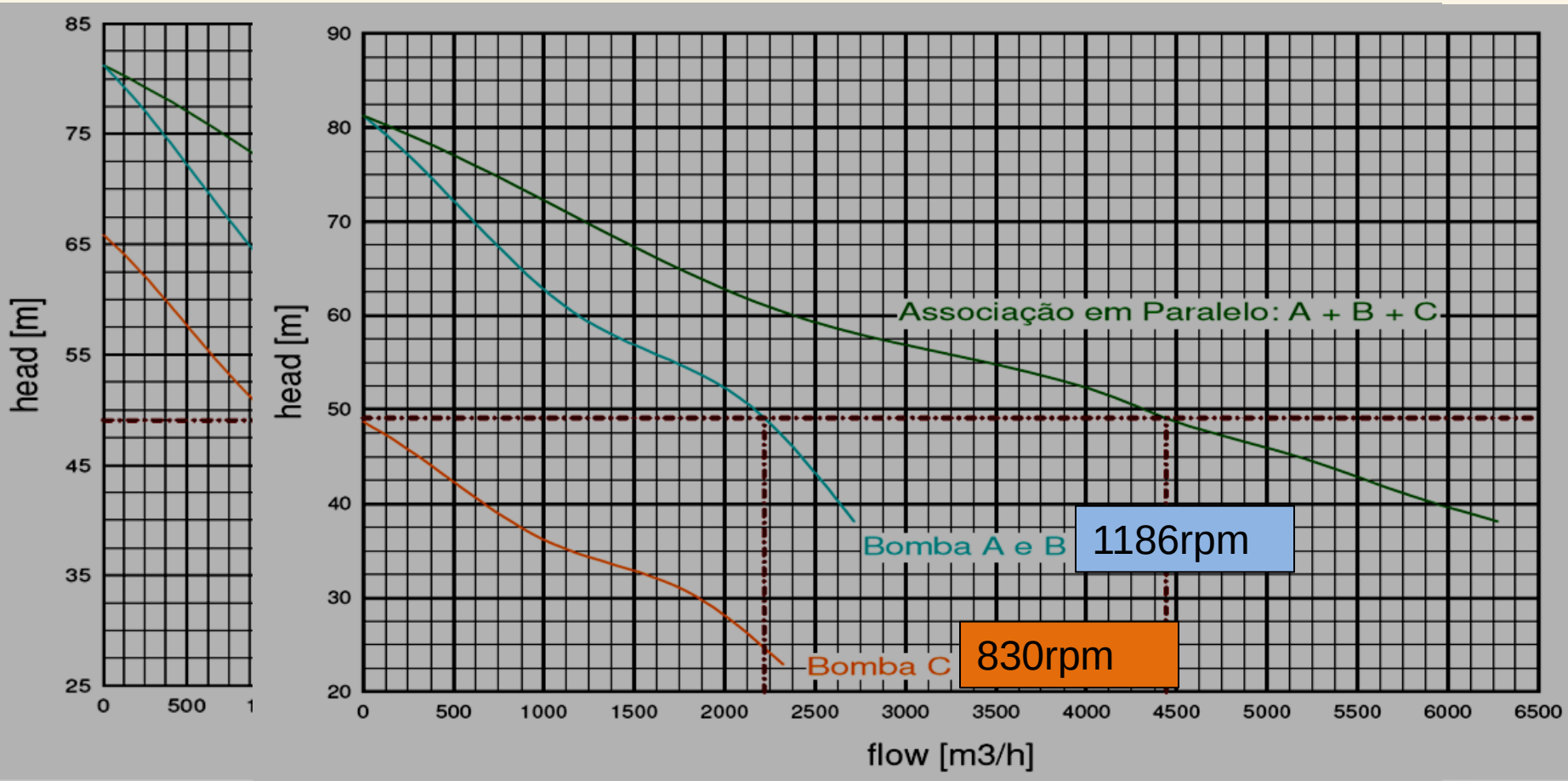


- Shaft diameter: 70mm
- Bearing span: 2000mm
- Bearing span according to API 610: max2250mm

Case Study - Vertical Pump in 3 Lagoas

Pumps A and B speed 100% = 1186rpm = 19,8Hz => 2218m^3/h – 49m – 370kW

Pump C speed 70% - 80% - 90% => 13,8Hz - 15,8Hz - 17,8Hz (1067rpm) => 1035m^3/h



Case Study - Vertical Pump in 3 Lagoas

Pump Min. Operating Water Level

Rising Pipe Natural Frequencies [Hz]			
	about Y-axis	**about X-axis**	**Figure**
1. Mode (1st classic bending mode)	1.1	1.1	Figure B-1
2. Mode (2nd classic bending mode)	6.7	6.8	Figure B-2
3. Mode (3rd classic bending mode)	18.6	18.7	Figure B-3
4. Mode (4th classic bending mode)	35.1	35.2	Figure B-4

Model: without shaft, sleeves and intermediary rubber bearings.

Water mass added to model

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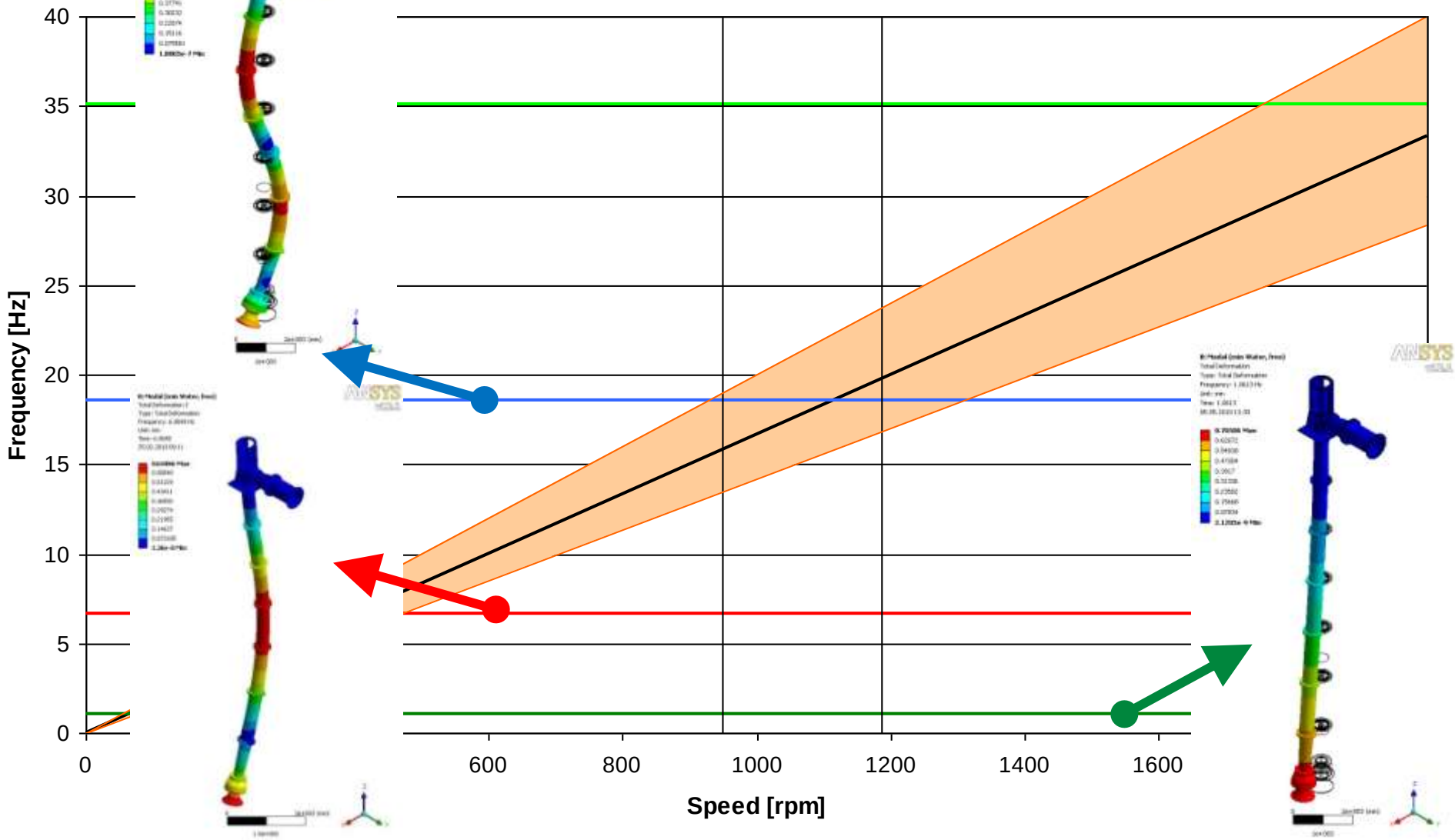
Without shaft, sleeves and rubber bearings

Campbell Diagram



Case Study - Vertical Pump in 3 Lagoas

Pump Min. Operating Water Level

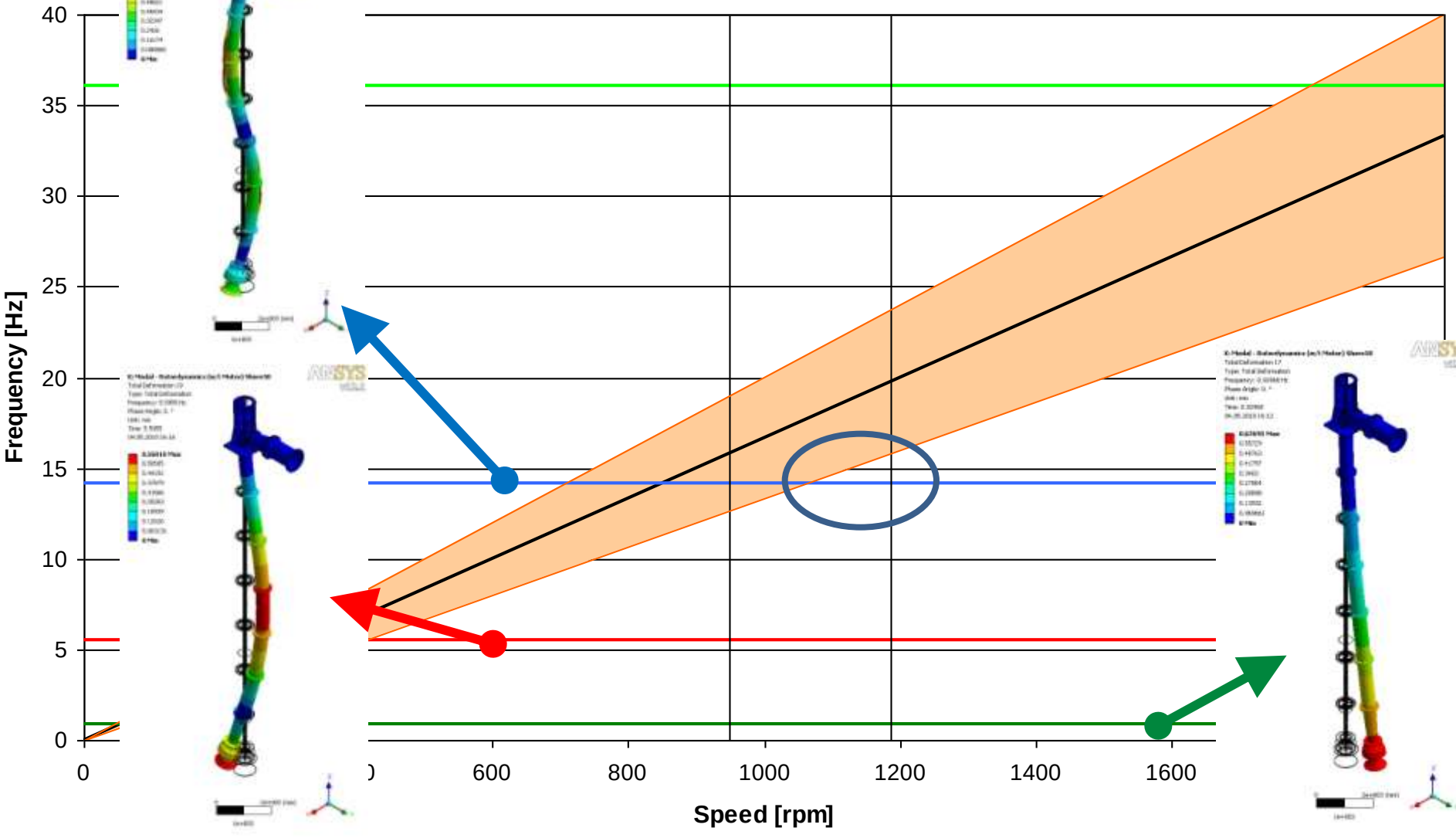
Rising Pipe Natural Frequencies [Hz]			
	about Y-axis	about X-axis	Figure
1. Mode (1st classic bending mode)	0.9	0.9	Figure C-1
2. Mode (2nd classic bending mode)	5.5	5.6	Figure C-2
3. Mode (3rd classic bending mode)	14.2	14.2	Figure C-3
4. Mode (4th classic bending mode)	36.1	36.3	Figure C-4

Model: with shaft, sleeves and intermediary rubber bearings, but not Rotordynamic effect included

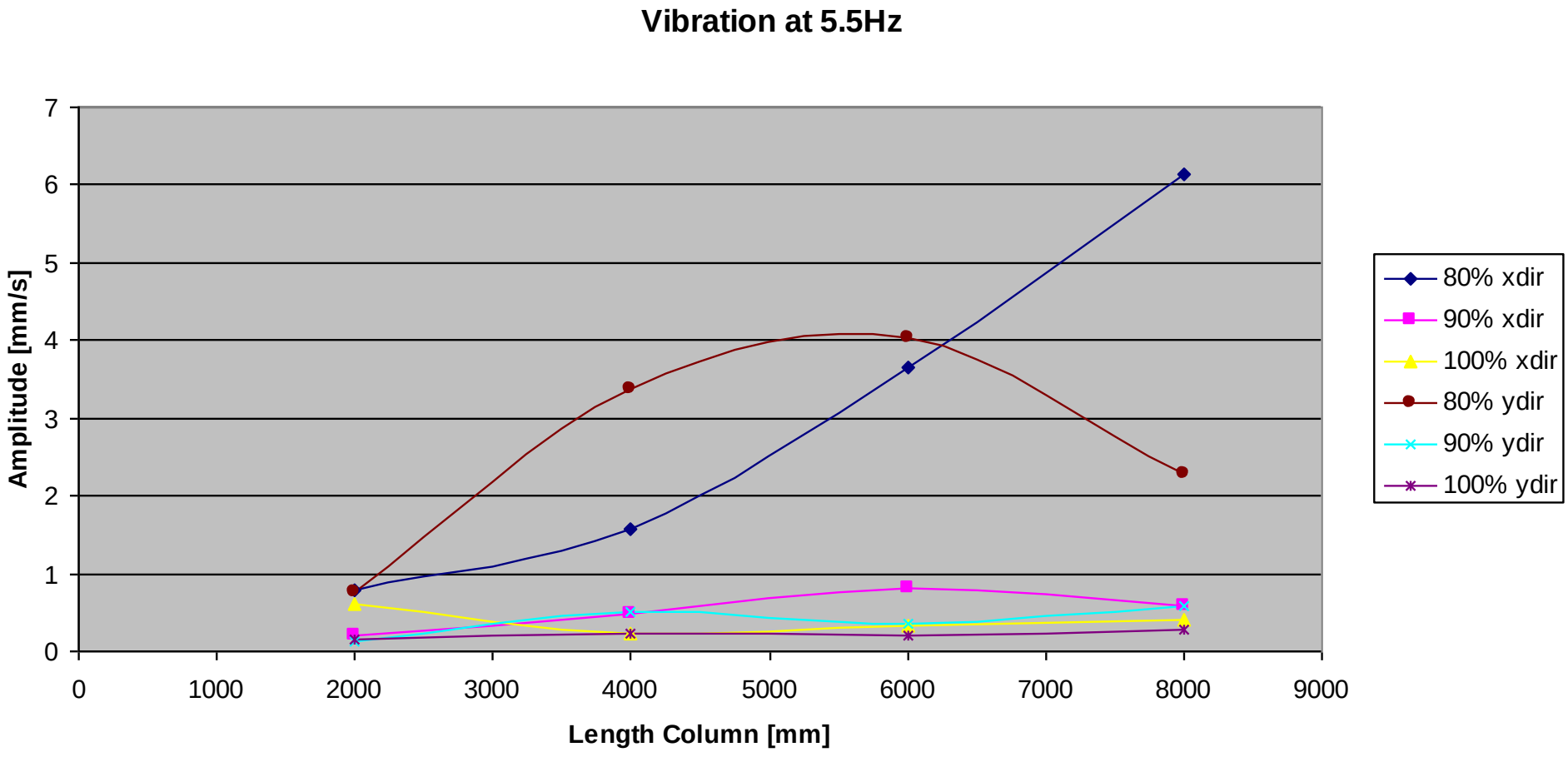
Water mass added to model

With shaft, sleeves and rubber bearings

Campbell Diagram

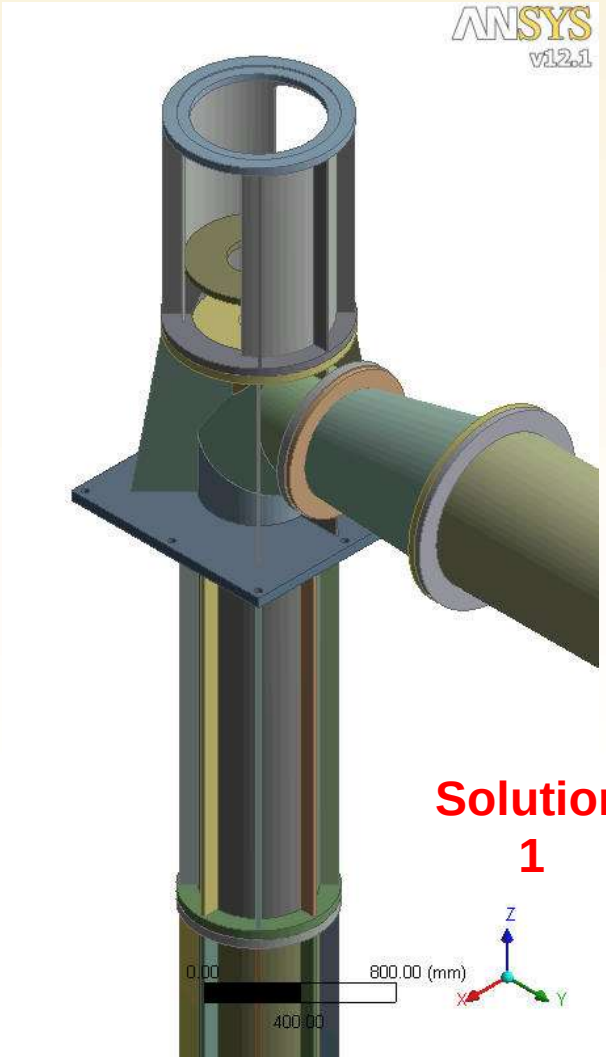


Case Study - Vertical Pump in 3 Lagoas

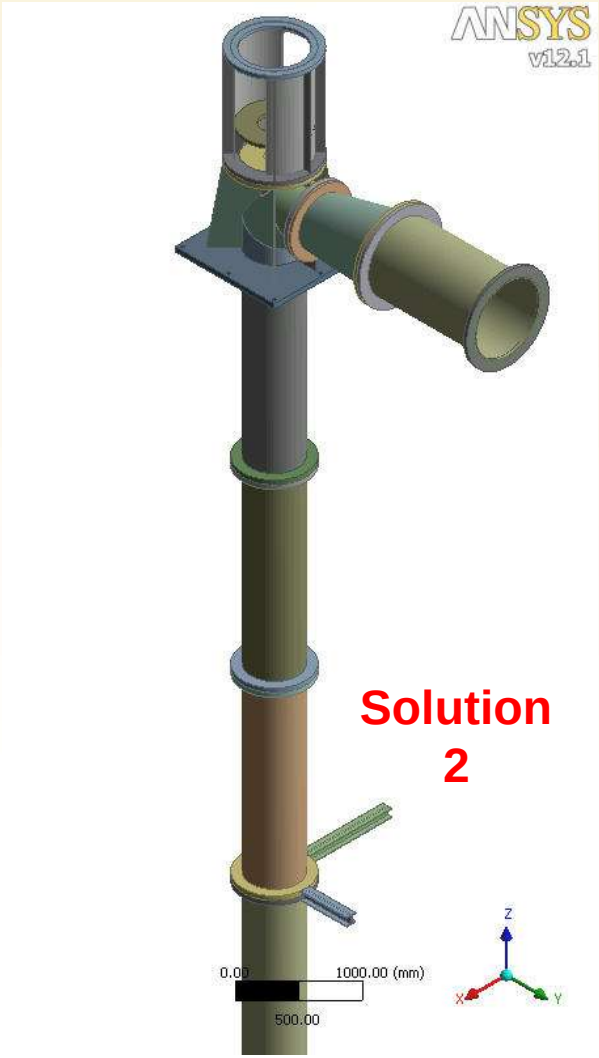


Vibration measurements at field: No resonance at 90% rated speed, but high vibration at 80% rated speed

Case Study - Vertical Pump in 3 Lagoas



Solution 1



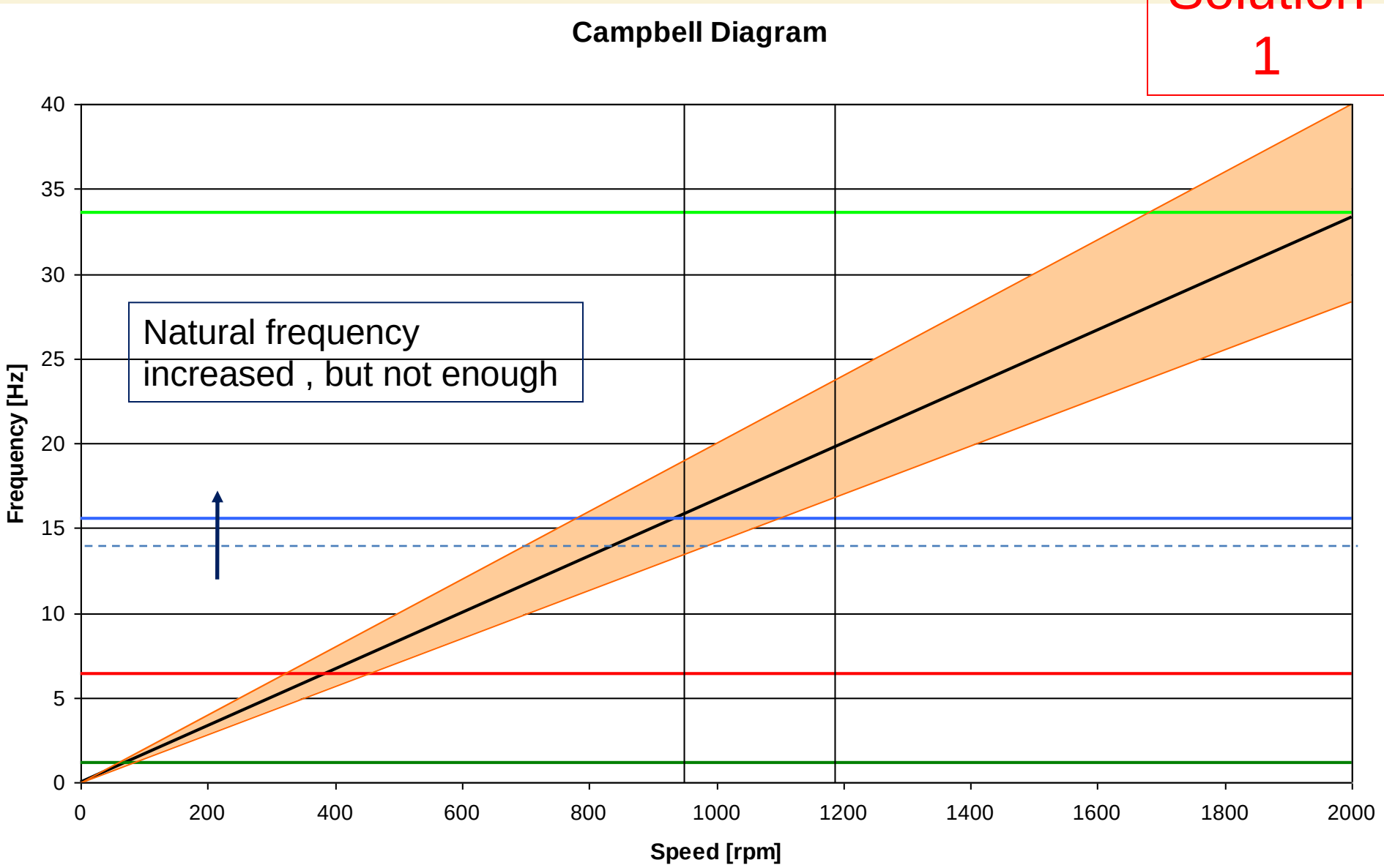
Solution 2

Two possible solutions:

1) Increase Natural frequency from ~14Hz to above 23Hz, by adding ribs in the column in order to increase stiffness

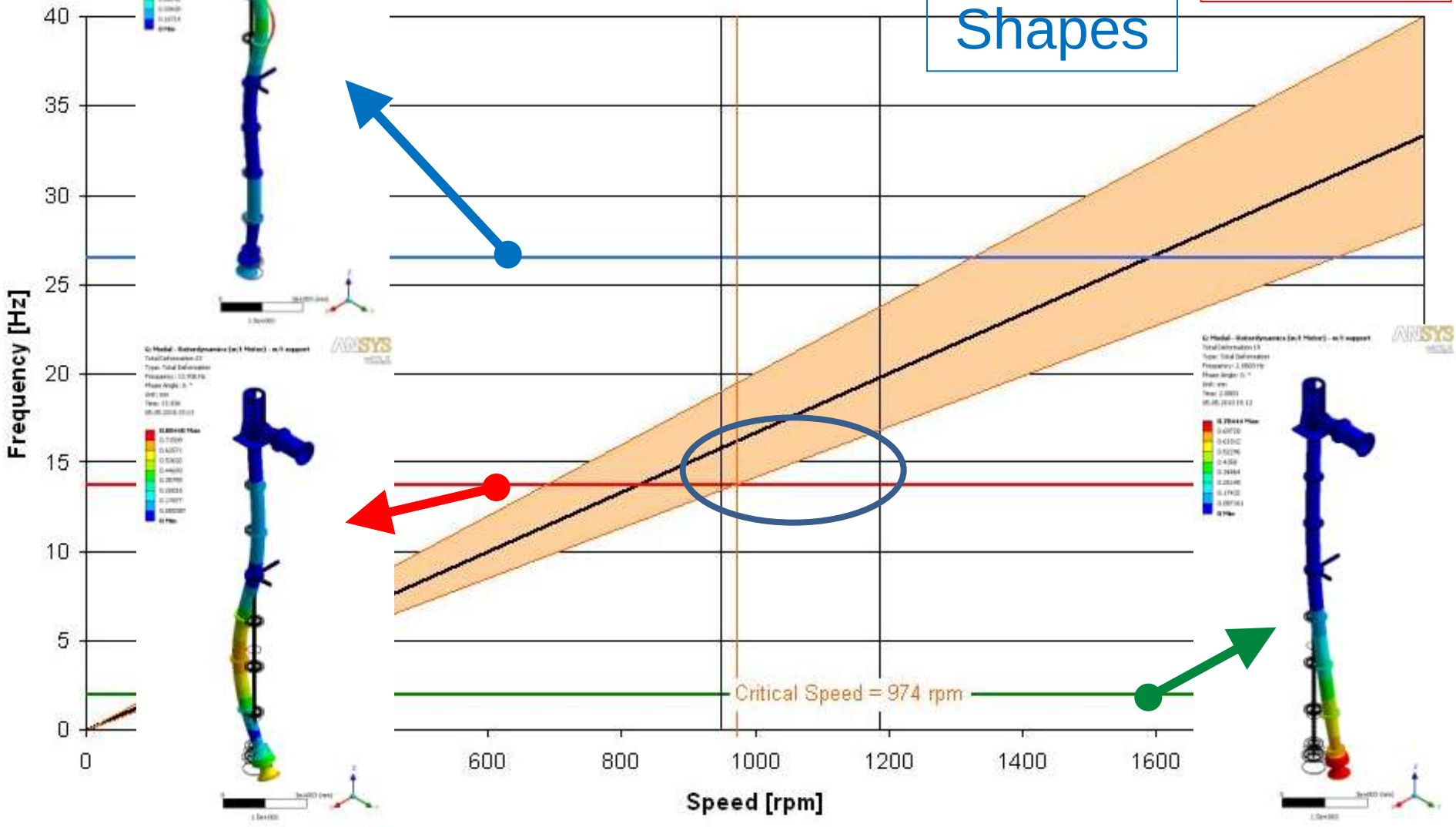
2) Modify Mode shape, by fixing column to concrete structure

Solution 1


Campbell Diagram
Natural frequency increased , but not enough
Frequency [Hz]
Speed [rpm]
0
5
10
15
20
25
30
35
40
0
200
400
600
800
1000
1200
1400
1600
1800
2000

New Mode Shapes

Solution 2



Case Study - Vertical Pump in 3 Lagoas

Conclusions

1. Learning: guidelines to Sales => orientation to customer in case of pumps in parallel with different speeds;

2. Optimum model => closest to reality, that means, enough information that explain what is happening at field;

3. To modify natural frequency taking in account separation margin: not ever to increase, but according to each configuration of project.

Case Study - Vertical Pump in 3 Lagoas

Gracias

Merci

Obrigado

Danke

Thank you

Grazie